TECHNOLOGY POLICY, NETWORK GOVERNANCE AND FIRM-LEVEL INNOVATION IN THE SOFTWARE INDUSTRY: A COMPARISON OF TWO BRAZILIAN SOFTWARE NETWORKS

Janaina Oliveira Pamplona da Costa

A thesis submitted in partial fulfilment of the requirements of the
University of Sussex for the degree of Doctor of Philosophy
in Science and Technology Policy Studies

November 2012

Science and Technology Policy Research (SPRU)
University of Sussex

I hereby declare that this thesis has not been submitted, either in the same or a different form, to this or any other university for a degree.

For my beloved parents,
Alfredo (*in memoriam*) and Zélia,
and my little girl Maria.

ACKNOWLEDGMENTS

Firstly, I would like to thank my supervisors, Professors Nick von Tunzelmann and Ed Steinmueller. Nick was crucial for my engagement in the Doctoral Programme, and it was he who introduced to me the network governance concept and suggested that work on this issue would be fruitful. He was a constant source of support, and always happy to see me on my ‘returns’ after intermissions, which was very encouraging. Ed formally took on the supervision much later, but throughout my years in SPRU he was always generous in providing moral and intellectual support, sharing his knowledge, reading preliminary versions of my work and giving illuminating feedback on work that was developed into the final chapters in this thesis. He has been a mentor whose support I shall be forever grateful for, and without which I would not have managed to finish this thesis.

I am grateful to Dr Matias Ramirez and Professor Paulo Tigre for agreeing to examine this thesis and for providing very valuable discussion during the *viva-voce* examination, which contributed to crucial improvements for the final version of the thesis.

I feel very lucky to have had the chance to be a research student in SPRU and I thank all of those who shared this experience with me: they are far too many to name here, but especial thanks go to my friends Rocio, Yun and Shova, with whom I shared many Saturday lunches in the later years - in the (so deserted/ghostly) Freeman Centre; Regina Silverio, Shova Thapa Karki, Rocio Alvarez and Carlos Sato for their help preparing and delivering the final version of this thesis to the post-graduate office; and Alessandro Teixeira, for his advice on how to manage the fees as a self-funded international student. I thank Pari Patel and Jackie Senker for giving me opportunities to work in their research projects; Ismael Rafols for taking his time to teach me the basics of Pajek; Professor Martin Bell for his comments at the beginning stage of this research; Janet French for her attention and assistance over the years; and SPRU Latin American Affairs Group for the valuable discussion on my research, especially Professor Carlota Perez and Dr. Matias Ramirez. My gratitude goes also to Cynthia Little, whose editing of the thesis and general moral support in the final days of the writing process is very much appreciated.

I am extremely grateful to all of those who gave their time for the interviews on which this thesis depends. They offered support by providing contacts and referring appropriate people for interviews. I am particular grateful to BNDES staff, CESAR staff, Cláudio Marinho, Ciatec staff, Dr Clênio Salviano, Dr Fábio Queda, Dr. Rafael Oliva, Associate Professor Dr. Sérgio Cavalcante, Dr. Solange Corder, Dr. Giancarlo Stefanuto, Fábio Pagani, Geovane Magalhães, Incamp staff, NGPD staff, Professors Carlos Américo Pacheco, Ricardo Dahab, Sérgio Queiroz, Sergio Salles-Filho, Silvio Meira, Wilson Suzigan, and Rodolfo Baccarelli and the Softex Campinas staff, and the Softex-Recife staff.

I thank my dear friends and colleagues: Cláudia Gama, Guillaume, Georgia Panagiotaki (Youli), Eva Dantas, Jonathan Sapsed, George Tsekouras, Andrew Grantham, Professor Howard Rush, Despina Kanellou, Rosane Marques, Mauricio and Célia Zuma, Harumi, Louisa Hatfield, Pippa Robinson, Rhona, Katie, Teresa, Carlos Sato and Neide Fujisawa, Isabel and Kleber Celadon, Regina Silverio, Fernando Perini and Rosana Costa, Emanoel Querette, Roberta and André Pião. Last but not least, I thank Carol and Zeca Brandão, who provided help and support in many ways during the fieldwork period in Recife.

Special thanks go to my dear friends Kay, Jeremy, and little Arlo; Heather, Maddie, Ed and Mark; and Marcia and Mika. They became my family in Brighton, and without their friendship, love and support my journey in England would have very much harder. I wish Brazil was ‘around the corner’ so that I could continue to see them as often as I have been used to in the past years.

I thank my family and friends in Brazil, who, although at a distance, supported me morally and many times financially, and also, Professor Lea Velho for her support over the past 15 years: she is a friend, mentor and role model.

Finally, I must thank my husband André, who started his DPhil journey in SPRU long before I did, but this gave me the opportunity to come to Brighton and SPRU. He supported me in many different ways through his love, patience, knowledge and encouragement. He set me the example of determination and, no less important, he supported me to finish my DPhil. I am eternally grateful to him.

I apologise in advance for anyone I have neglected to mention.

UNIVERSITY OF SUSSEX

Janaina Oliveira Pamplona da Costa Doctor of Philosophy

Technology policy, network governance and firm-level innovation in the software industry: a study of two Brazilian software networks

SUMMARY

This thesis examines how regional level network governance and structure influence the effectiveness of technology policy to improve local firms' innovativeness in a developing country context. It examines whether network governance and structure have a consistent influence on the innovative performance of firms located in developing country regions that show different levels of socio-economic development. The empirical evidence is based on a multiple case study of two regional software networks in Brazil – Campinas and Recife – in the period 2006 to 2009.

Studies show that regional networks and industry growth in developed countries involve some degree of co-evolution. Networks are supposed to foster firm-level innovation, since government policies tend to assume that firms learn by interacting and that new knowledge is essential for innovation. Inspired by these findings, governments in developing countries often seek to address industry and regional development by encouraging the formation of regional networks. Policies aimed at supporting development of networks have become an important instrument to support interaction among firms, and between firms and other network actors. However, the investigation of networks, and especially the formation of dyadic ties and network consistency, is rarely the subject of empirical work on developing countries' innovation systems. Existing studies of networks tend to provide little empirical evidence on multi-organisational interaction and often do not investigate the related controlling mechanisms, which are crucial for a better understanding and more effective policies. This thesis, using a single analytical framework, provides a study of technology policy, multi-organisational network governance and structure, and firm level innovative performance.

The research examines two Brazilian software industry networks established in the early 1990s, promoted by a national government programme to support the formation of regional networks. The histories of the information and communication technology (ICT) industries in the two regions are very different. The ICT industry in Campinas benefited from long-term national support, while the ICT industry in Recife received little direct support through national policies. The history of each network (i.e. infancy and evolution) is described until 2009. National government programmes to support these networks were complemented by local and state level policies aimed at developing the respective regional software industries. We observe the innovative performance of local firms participating in these regional networks in the period 2006-2009. The finding from this doctoral research is that network governance and structure had a mixed influence on the effectiveness of government technology policy to promote firm-level innovation in the networks investigated; the thesis sets out some of the reasons for the differences in firm level innovative performance in the two networks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES AND BOXES

LIST OF ABBREVIATIONS

ABES	Brazilian Association of Software Producers
ABDI	Brazilian Agency for Industrial Development
AD-Diper	Pernambuco Economic Development Agency
ATI	Pernambuco State Agency for Information Technology
Anprotec	Brazilian Association of Agencies Promoting Advanced Technological Projects
APEX-Brasil	Brazilian Trade and Investment Promotion Agency
ASSESPRO-PE	Brazilian Association for Information Technology Firms - Pernmabuco Office
Banorte	Banco Nacional do Norte
BNDES	Brazilian Development Bank
CAPES	Agency for the Support and Evaluation of Graduate Education
CEFET-PE	Pernambuco Federal Centre for Technological Education
CGEE	Center for Strategic Studies and Management in Science, Technology and Innovation
CEPETRO	Petroleum Study Centre – State University of Campinas
CESAR	Recife Center for Advanced Studies and Systems
CESAR.edu	Recife Center for Advanced Studies and Systems- Education Division
CIATEC	The Company for the Development of Campinas High-Technology Park
Cin – UFPE	Informatics and Technology Centre –Federal University of Pernambuco
CIS	European Community Innovation Survey
CMMI	Capability Maturity Model Integration
CNAE	National Classification of Economic Activities
CNDI	National Council for Industrial Development
CNI	National Confederation of Industry-Brazil
CNPq	National Council for Scientific and Technological Development
CONCLA	National Classification Commission
CPqD	Research Centre for Information and Communication Technology
CTI/CenPRA	Renato Archer Information Technology Centre
ERP	Enterprise Resource Planning

FACEPE	Pernambuco Research Foundation
FAPESP	The State of São Paulo Research Foundation
FEEC-UNICAMP	School of Electrical and Computing Engineering-State University of Campinas
FDI	Foreign Direct Investment
FINEP	Research and Projects Financing-The Brazilian Innovation Agency
FNDCT	National Fund for Scientific and Technologic Development
Fundo CRIATEC	Venture Capital Fund
IBGE	The Brazilian Institute of Geography and Statistics
IC-UNICAMP	Computing Institute – State University of Campinas
ICT	Information and Communication Technology
IEL	Euvaldo Lodi Institute
Incubanet	The Pernambuco Network for the Promotion of Innovative Entrepreneurship
INCUBATEP	ITEP Incubation Programme
INdT	Nokia Institute of Technology
Inova UNICAMP	Innovation Agency, State University of Campinas
InovaSoft	Innovation Agency-Software Division, State University of Campinas
IPI	Industrialised Goods Taxation
IPR	Intellectual Property Rights
ISS	Taxation over Service
IT	Information Technology
ITBC	Information Technology Business Centre
ITEP	Technological Institute of Pernambuco
LabSEC- UFSC	Computing Security Laboratory, Federal University of Santa Catarina
LPA	Local Productive Arrangement
LPAIS	Local Productive Arrangements and Innovation Systems
MCT	Brazilian Ministry of Science and Technology
MDIC	Brazilian Ministry of Development, Industry and Commerce
MNC	Multinational Corporation
NGPD	Porto Digital Management Unit
NIT	Technological Innovation Nucleus
NSI	National System of Innovation

NTBF	New Technology-Based Firms
OS	Social Organization
OSCIP	Public Interest Civil Society Organization
PAEP	Paulista Economic Activity Research
ParqTel	Pernambuco Technological Park
Pintec	Technological Innovation Research
Prosoft	BNDES Programme for the Development of the National Software and Services in Information Technology Industries
PSI-sw	Sectoral Integrated Project for Software Exports and Related Services
PUC-CAMP	Campinas Catholic University
R&D	Research and Development
Recife BEAT	Recife Basis for High Technology Entrepreneurship
S&T	Science and Technology
SEBRAE-Campinas	The Brazilian Service of Support for Micro and Small Enterprises – Campinas Office
SEBRAE-PE	The Brazilian Service of Support for Micro and Small Enterprises – Pernambuco Office
SECTMA	Pernambuco Secretary of Science and Technology and the Environment
SEI	Special Secretariat of Informatics
SEPIN	MCT-Secretary for Policy in Informatics
Softex-Recife	Recife Software Technology Centre
SPTec	São Paulo Technological Park System
SSI	Sectoral Systems of Innovation
STEM	Science, technology, engineering and mathematics
UFPB	Federal University of Paraíba
UFPE	Federal University of Pernambuco
UFRPE	Federal Rural University of Pernambuco
UNESP	State University of São Paulo
UNICAMP	State University of Campinas
UNICAP	Pernambuco Catholic University
UNIMAR	Marília University, São Paulo State
UPE	University of Pernambuco
USP	University of São Paulo

CHAPTER 1 - INTRODUCTION

1.1 The Issues Addressed

The thesis examines public policies aimed at: i) fostering the initiation and development of regional network for high-technology activities; ii) supporting effective network governance and structure; and iii) encouraging of firm-level innovation in a developing country context. The empirical evidence is derived from the experience of two Brazilian regional software networks. In this thesis, we use the term 'network' to refer to a structure of formal and informal collaborations and common interest relationships among (for profit and non-profit) organisations. The primary focus of the thesis is formally recognised collaborations within the networks examined.

The relevance of network arrangements to support firm-level innovation has been addressed extensively, and especially in the systems of innovation literature, which claims that firms learn through interaction, and that this learning includes new knowledge that is essential for innovation (Cimoli, 2002; Freeman, 1987, 1991; Lundvall, 1992b; Nelson, 1993; Powell and Grodal, 2005). Evidence on the significance of network arrangements (especially for developed countries), including networks of individuals and informal networks, for innovation is often interpreted as meaning that firms that are embedded in network arrangements are likely to be more innovative (Castilla *et al.*, 2000; Grasenick *et al.*, 2008; Herrigel, 1993; Lazerson, 1993; Saxenian, 1990; Uzzi, 1997). Network studies take account of the fact that firms are not isolated actors and will be influenced by dyadic ties formed with other network actors. In addition, and significantly, it is not necessarily the strength of a tie that determines its value because ties can play different roles (Granovetter, 1973) and the structure in which they are embedded is also critical (Storper, 1996).

Networks can be seen as emerging entirely from a process of dyadic tie formation, arising through happenstance or chance, and that the strength of inter-organisational ties is the result of personal interactions that reflect personalities and various experience. Alternatively, the processes of network tie formation and the evolving strength of ties can be seen as reflecting the purposive aims of organisations that take account of some parts or all of the structure of the network. This latter view suggests the presence of agency in the formation and evolution of networks.

An understanding of both paths to the formation of networks is relevant to an investigation of network development, which includes governance issues (where governance meaning coordination), and calls for a definition of network governance and structure. We would define *network governance and structure as inter-organisational coordination exerted in a particular institutional setting*[1] and understand coordination as occurring when two (or more) network actors pursue a common outcome and establish a tie in order to pursue it (Bevir, 2009: 57). In this thesis we investigate firm-level innovation, where the innovation is an outcome pursued by network actors, and examine dyadic ties taking account of the possible influence of these ties and their coordination (see Chapter 5 for a more in depth discussion). The institutional setting influences the agency exercised in the formation of ties and the exertion of control in the effort to shape the overall structure of the network. The institutional setting also may involve different levels of investigation, such as local, regional, national or global, which aligns with the systems of innovation approach introduced by Freeman (1987).

The possibility of governance, and the corollary that some acts of governance may be superior to others, suggests that governments might want to implement technology policies to support the creation of networks, the expected by-product being networks effective governance as a means to improve firm-level innovation. For instance, US federal government expenditure on technological development activities in the Route 128 and Silicon Valley regions (Saxenian, 1994), shows that geographically concentrated government investment can promote the formation of a self-organising network involving firm specialisation. Although the contexts are different, the experiences of industrial districts such as Modena in the Emilia-Romagna district of Italy (Lazerson, 1993) and Baden-Württemberg in Germany (Herrigel, 1993), illustrate successful government intervention to support regional network development.

The confluence of successful experience in developed economies and growing awareness of the systems of innovation approach since the late 1980s (Freeman, 1987; Lundvall, 1992b; Nelson, 1993) has inspired developing country governments to make network formation an element of their technology policies and to invest in

[1] Jones *et al.* (1997: 913) define network governance as inter-firm coordination. Here we extend their conception to include all organisations (profit and non-profit) that are part of the network.

the creation of local and regional networks. However, it is still debateable whether and to what extent government policies to induce network formation and development are effective. Based on perceptions of experience such as that mentioned above, governments in developing countries have assumed that regional networks can be engineered or arranged to become efficient mechanisms to support both economic catch-up with the developed countries and laggard regions in the national economy catching up more generally. This was the aim of policies formulated for the Brazilian software industry (see Chapter 3). Identification and replication of policies implemented in developed countries has been common practice in Brazil since the early stages of its industrialisation (Pacheco and Corder, 2009).

There are three aspects of government intervention related to individual and collective gain. Firstly, from the social welfare perspective, government intervention should be social welfare improving. Since any intervention will involve a re-allocation of resources (government's or those of other actors') and possible negative effects on social welfare, it is important to establish *whether government intervention is necessary*. That is, whether the absence of government intervention lead to inferior social welfare outcomes. For example, if networks would be beneficial, but their formation unlikely, would government intervention catalyse or stimulate the engagement of actors sufficient to lead to the development or exchange of relevant knowledge? A positive answer to this question is needed to support government intervention. For instance, allocating resources to only a small number of (perhaps minor) actors might result in these resources being wasted, which would be welfare reducing compared to some more productive use of these same resources. There might be alternative and more effective support than networking. The lack of consensus about the level of gain to be expected from intervention and the level of risk that the government bears in undertaking such intervention suggests the need for research to better assess these issues.

Secondly, we need some clarification about *whether network actors and agents are likely to respond to government policy intervention*. This requires some assessment of the 'feasibility' of intervention. Since the desirable features of networks flow from the voluntary actions of their participants it is possible that little or nothing might result from government incentivised or directed efforts to create 'networks'. Network actors may act opportunistically to fulfil the requirements of the intervention in order to receive the incentive, or comply with the formalities without expending the additional effort required to derive value from network membership. The history of the actors matters here since it may influence their responsiveness to government intervention or their willingness to explore with their new ‘partners’ whether there are any gains to be derived from a relationship that has been foisted upon them.

Thirdly, there is a need to investigate *whether the governance process established by the government intervention will be more effective than would have followed from autonomous governance by network participants*. This implies that governments intervene not just in network formation, but also in the governance of ongoing networks, not least to establish some accountability for their investment. How this accountability should be demonstrated then becomes an important regulatory issue – can governments distinguish networks that have ‘gone wrong’, for example collusive and anti-competitive networks (including those dominated by single actors), which will be more likely to suppress than to foster innovation, and to engage in other actions that may be social welfare reducing (e.g. collusive pricing). In the following paragraphs, we investigate these three issues in more detail to lay the foundations for the investigation in this thesis.

The study of *whether government intervention is necessary* is related to the debate on the role of state, whose participants include advocates of markets as efficient economic controlling mechanisms (Friedman, 2002). This group would argue that government intervention is superfluous (markets achieve the desired outcome without intervention) or undesirable (government failure could lead to social welfare diminishing outcomes).[2] Advocates of government intervention identify market shortcomings that could lead to market failure, some of which might be overcome or mitigated through government intervention.

Advocates of market control argue that market price and profit incentives are sufficient for an efficient resolution of the problems of resource allocation. They often assume that there is no persistent information asymmetry among economic

---

[2] Krueger (1991) provides a detailed discussion of government failure in developing countries, relating it to problems of failure of commission (e.g. the high-cost public sector enterprises engaged in economic sectors traditionally not associated with the public sector (Krueger, 1991:4) and failure of omission (e.g. the deterioration of transport and communication facilities as well as failure to maintain infrastructure facilities (Krueger, 1991: 5).

agents and that market power in transactions is ephemeral because of the competitive response that such market power elicits. A further view of markets is their flexibility; economic agents can freely access or leave markets according to their perceptions of the profit making opportunity. This group claims that there is no need for governments to intervene in the economy; markets will achieve the most efficient allocation of resources in production and consumption, given the prior endowments of participants. There are variants of this view. One is that government intervention might be able to achieve welfare improving outcomes by prioritising subsidy of specific industries (sometimes called 'picking winners') instead of indiscriminate and uniform tariff protection (Baldwin, 1969:304). Another, more pessimistic view, is that governments will inevitably create more distortions and inefficiency through intervention and that 'picking winners' is beyond the competence of governments.

However, the assumptions made by the advocates of markets are being questioned increasingly by their critics who ague that market failures are frequent, and that markets need to be monitored; they argue also that pure market mechanisms raise as many problems as they solve (Boyer, 1997). Examples include: i) provision of public goods, related to 'non-rivalry' and 'non-excludability' issues;[3] ii) the existence of imperfect competition resulting from collusion or imperfect information, and iii) the presence of externalities, which by definition are not subject to market exchange, and whose socially optimal resolution requires state intervention (e.g., taxing negative externalities - such as pollution, and subsidising positive externalities - such as education). Those who point to the frequency of market failure argue that governments need to intervene in the economy to adjust or correct market imperfections, and that doing so will increase social welfare.

On the other hand, market advocates, particularly those pessimistic concerning government intervention, claim that government intervention suffers from the following four types of failure: i) information problems; ii) agency problems; iii) rent-seeking behaviour; and iv) bureaucratic capture. For instance, Krueger (1997) discusses government intervention in developing countries where infant industries were protected following an inner-oriented industrial policy (for example, based on an import substitution model), where the problem of rent-seeking behaviour by the

[3] Goods are non-rivalrous if their use or consumption does not interfere with the use or consumption of someone else (e.g. software applications); a non-excludable good is a good for which there are no practical means for excluding common use (e.g. national defence).

private sector was commonly found. Although supporters of government intervention recognise that government failures occur, developmental state scholars maintain that the state should intervene in the economy in order to avoid, minimise or correct market failure mechanisms (Evans, 1995). The market imperfections related to technology require government intervention by means of technology policy.

Technology can be defined in terms of the knowledge embodied in machines and in terms of the person-embodied knowledge of those who use codified and tacit knowledge to develop, operate and improve these machines (Pavitt, 1987). These features of technology raise issues related to technological spillovers in the economy, when "knowing how to do one thing is consequent on knowing how to do closely linked things" (Storper, 1995:895), which endows technology with some non-rival and non-excludable goods characteristics. These characteristics may push actors to take actions to remedy the possible negative effects of economic externalities (such as free-riding on others' investment in innovation) that have the potential to undermine market competition (e.g. by creating market power through intellectual property rights protection). In addition, technology involves asymmetric knowledge between its developers and users, which is additional market power that affects market competition and the efficient supply of goods and services. Technology developers are not driven out by competition because those with better knowledge restrict their output (or the equivalent, demand higher prices) in pursuit of higher profits, which creates a higher cost ceiling making it possible for less profitable companies to afford (inefficient) higher costs (Steinmueller, 2010). While the less profitable companies eventually will be abandoned by investors seeking higher returns, this process is not likely to occur instantaneously.

Developmental state scholars (for instance, Chang, 1994; Evans, 1995) argue in favour of government policy intervention, and government intervention through technology policy is necessary for economic development (Pavitt, 1987). Therefore, examining their arguments is appropriate in light of the policy aims of the Brazilian government. In addition, considering that the technology characteristics mentioned above may be exacerbated in the case of developing countries where insufficient scale, inefficient markets and infant industries may reduce innovative performance and economic growth, some further investigation is required into how government policy can influence networks in developing countries.

The above discussion leads to the second issue that requires clarification, which is *whether network actors and agents are likely to respond to government policy intervention*. The original formation and evolution of a network can influence the responsiveness to government intervention of its actors and agents. Networks can be emergent (i.e. based on incidental interactions) or purpose-built (i.e. strategically created), and technology policy formulation and implementation must take account of the history (if any) of the relations between the actors that might be involved in the network.

Emergent regional networks arise from the voluntary searches of actors seeking mutual gain, and are generally localized in a bounded territory, although some network nodes may be located outside the region (investigated using the concept of inter-network collaborations). In emergent networks the key actors are already accessible and interacting with one other; government needs to promote and foster the continuity of these interactions if the network was established to achieve a short term goal. Government may be able to anticipate changes that would enhance network development (this relates to the third issue discussed further below). In this case, policy intervention may be linked to promoting the inclusion of new actors in the network, recreating existing network actors, or institutional changes (e.g. in the rules governing public research centres or business organisations). Then, one would expect *ex-ante*, that the network would emerge bottom-up from the arrangements among network actors searching solutions to their problems or promoting projects related to future network development. In this case, the influence of government policies on network actors is likely to be lower than in the case of purpose-built networks.

Purpose-built regional networks may emerge as a result of government policy intervention following selection of a region to host public and private investment directed towards a particular industry. The organisation of private investment is most often orchestrated by government. The selection of a region may be related to its attributes, for example natural resources, expertise developed by local suppliers including (among others) knowledge (especially universities) and technology (most often technology centres). The creation of regional networks occurs in two stages: i) first government assures accessibility to the key actors to support the regional network through their physical presence or easy distance accessibility; and ii) second government establishes mechanisms to foster and support interaction among the actors in the network. Intervention should be based on the assumption that the actors may have asymmetric information, may be misinformed about or may have inadequate access to other actors. In this case, one would expect *ex-ante*, a top-down arrangement in which technology policy is more likely to influence actors' interactions (at least in the early stage of network development). In this case, network actors and agents will be more dependent on policy incentives and, therefore, more responsive to policy implementation than in emergent networks where the actors follow their own agendas.

In addition to network creation issues (emergent or purpose-built networks), there are the issues of actors' responsiveness to government policy implementation, such as the motivation for actor-to-actor tie formation. The motivations will likely differ in every case, but will include past personal relationships (friendships or acquaintanceships which commonly involve trust), common professional background (former class mates or university tutors-tutees, which imply common interests and visions about the nature of the available opportunities), cost savings, and geographic or social proximity.

Although the motivations for actor-to-actor tie formation may vary, their formation is likely to be related to the stage of network emergence or the response of the actor to government intervention. In emergent networks, ties are likely to be motivated more by 'trust', where 'trust' is understood as contingent on the context and quality of relationships formation, than by other factors (e.g. opportunities). Here the expectation *ex-ante* of policy implementation is that once government incentives are put in place, actor-to-actor ties will be more likely to be maintained or to increase over time.

Government capability to foresee the changes required to spontaneously formed networks on the one hand, and extreme government intervention directed at creating networks on the other hand, are related to the third issue we investigate, that is, *whether the governance process established as the result of government intervention will be more effective than the process that would emerge from autonomous governance by network participants*. This issue has two aspects. Firstly, governments must possess the resources or powers of enforcement and also the capabilities to assess network operation and existing or potential barriers to the achievement of desired goals, for example innovation. Secondly, interventions that potentially are social welfare enhancing may fail or have deleterious effects at the network level.

This thesis aims to explain to what extent government technology policy is able to influence network formation and growth and to assess whether these processes, including the resulting network structure, have an effect on firm-level innovations. We take account especially of the fact that firms are embedded in particular settings, which also may exert an influence on the returns to investment for firms involved in innovation and other activities.

The above discussion, combined with reflections on the literature in Chapter 2, suggest the following two groups of research questions:

Research Questions Group A:

Question A1

In considering government technology policy to promote firm innovation through networks in a developing country context, do regional level network governance and structure influence policy effectiveness? If they do, what features of governance and structure should be taken into account in policymaking?

Question A2

What, if any, is the responsiveness of network governance and structure to technology policy aimed at the promotion of networks in a developing country context? Does government policy promotion of networks and efforts to control network structure increase the effectiveness of technology policy aimed at improving innovative performance in a developing country context?

Research Questions Group B:

Question B1

Do network governance and structure have a consistent influence upon the innovative performance of developing country firms set up in regions with different socio-economic development indicators?

Question B2

In assessing the effectiveness of technology policy in developing countries, are there differences in policy effects when comparing advanced and relatively backward regions within a country?

The research for this thesis was aimed at answering these questions in the specific context of an intermediate developing country, Brazil, where there is disparity among regions in terms of economic, social and industrial development.

1.2 Scope and Broad Approach of the Thesis

It is assumed that firms are at the core of the innovation system, because technological accumulation is localized mainly in firms and they are supposedly the network actors that most benefit from innovation (Bell and Pavitt, 1992; Malerba, 2004: 24). This assumption leads to a focus on network governance and structure related to firm-level innovations in developing country contexts and especially Brazil.

Since the end of the 1990s, studies of innovation in Brazil have adopted the Local Productive Arrangement (LPA) approach, in which different regions are investigated in relation to: i) market penetration of the local arrangement; ii) use and development of local competencies in the activities performed under the arrangement; and iii) the mode of governance within the LPA, with the aim of elucidating the decision making power among actors, that is, whether the LPA follows a hierarchy or network type (Cassiolato and Lastres, 2003).

We focus on network governance and structure to investigate the dyadic ties formed by firms with regard to their innovation activities; we differ from the LPA approach mainly with regard to the level of analysis and methodology applied. The level of analysis investigated here refers to the nature of and motivation for each tie in order to achieve a better representation of the network, which allows an interpretation of the network structure (including the institutional setting) and how government policy effectiveness relates to network governance and structure. The methodology for this analysis draws partially on social network analysis methods, especially with regard to visual representation of the network, which provides insights into bridges within networks and the structure of the network. This methodology supports discussion of the engagement or disengagement of key actors in the main cluster of nodes and how information is spread within the network.

The thesis is based on original qualitative data on firm level innovations, collected mainly through face-to-face interviews. This method of data collection was chosen because: i) quantitative data, such as patents, are not considered an appropriate proxy for innovation in the software industry; ii) innovation surveys in Brazil are a recent phenomenon, and so far, few of the questions relate to the information technology (IT) (although this is being remedied); and iii) quantitative data, such as required for social network analysis, capture neither historical trends nor regulatory and institutional issues (Grasenick *et al.*, 2008 :309-310), both of which may prove extremely relevant for explaining collaboration among network actors and network structure.

Firm-level innovations were identified for the period 2006-2009, according to Oslo Manual (OECD, 2005) recommendations. Thus, innovations were measured as the commercialisation of new product or services and classified by their degree of novelty: i) new to the firm, ii) new to the regional market; iii) new to the national market; or iv) new to the international market.

Network governance studies tend to analyse either the dyadic ties within networks *or* the structure of the networks. In this thesis we integrate the elements of dyadic ties *and* network structure as well as government technology policy, within a single analytical framework (Chapter 5, Figure 5.2). The analytical framework is applied to the investigation of each separate network.

Network governance is examined through the dyadic ties among firms, and between firms and other network actors. The examination of dyadic ties provides evidence on the following: i) the features of and motivations behind the network ties created between firms and other network actors; ii) the number of ties created by each firm; iii) the frequency of collaboration related to each tied actor; and iv) the location of the collaborating partner. The classification of the features of tie creation are based on the Oslo Manual (OECD, 2005) and supported the identification of consistency between four sub-networks (business, skills, technology and financial) within the main network.[4] The motivations behind each tie provide evidence on firms' connectivity, classified as tightly-connected or loosely-connected ties. Network

[4] The rationale for grouping the actors into four sub-networks is based on the argument that innovation networks are a sub-set of a system of innovation. Chapter 5, Section 5.3.2.1 discusses this in more detail.

structure is examined from emergence to 2009 and provides evidence on how the network was formed (e.g. emergent or purpose-built) and its evolution and maturity.

A multiple case study methodology is employed (Yin, 2003). The choice of case studies was based on regions exemplifying different contexts that change over time and warrant in-depth analysis. The two case studies of software industry regional networks, Campinas and Recife in Brazil, were selected based on the following criteria: i) they were targeted by government technology policy aimed at industrial regional network creation; ii) they were affected by the same national government programme; iii) the networks are based in regions at different stages of industrial development; and iv) the networks are in regions with different levels of socio-economic development. The two networks were formally created in the early 1990s as a result of the national Brazilian government Softex Programme (see selection criteria (i) and (ii) above, and Chapter 3). Also the two networks are located in regions at different stages of industrial and socio-economic development (selection criteria (iii) and (iv) and Chapter 4).

The thesis is positioned within the literature on sectoral systems of innovation in developing countries, government policy intervention and local firm-level innovation, and the investigation of regional networks. Section 1.3 describes the approach adopted to these issues.

1.3 Structure of the Thesis

The thesis is organised as follows. Chapter 2 reviews the systems of innovation, network governance, technology policy and firm-level innovation literature to address the research questions set out above. The systems of innovation literature examines the importance of local, regional and national institutions and organisations required to support innovation performance at firm level. The network governance approach includes a discussion on the relevance of network arrangements for inter- and intra-firm collaboration with regard to firm-level innovation activities, and introduces concepts relevant to the discussion on dyadic tie formation (Granovetter, 1973), network structural holes (Burt, 1992) and network openness. As already mentioned, technology policy may be crucial for network creation and development. We discuss the issues addressed by technology policy and the implications of its implementation. Chapter 2 concludes with a discussion of why firm-level innovation is relevant and the approaches that can be used to explain firm-level innovation performance. Chapter 2 identifies some issues not covered in the literature and situates the research questions in a theoretical context which is re-considered in light of the experience presented in the succeeding chapters of the thesis.

Chapter 3 provides an overview of industrial development in Brazil, and introduces the mechanisms enabling industrial development, highlighting the most relevant organisations created by national government to support local science and technology activities and to foster technological progress and economic development. This is followed by a section devoted to the software sectoral system of innovation, which provides the basis for a discussion of the Brazilian software industry's emergence and evolution.

Chapter 4 provides background information on the structure of the two regional networks we examine, Campinas and Recife. We investigate their early stages and evolution, discussing their main characteristics such as age, maturity, information and communication technology (ICT) related history and government technology policies implemented in the regions that could be related to software firms' innovation performance in each region (examined in more detail in Chapters 6 and 7).

Chapter 5 describes the methodology used in this thesis and explains the choice of research methods. The bounded focus of the empirical research is discussed along with the core concepts supporting the design of the analytical framework and the research strategy. The chapter concludes with a description of the data collection and analysis.

Chapter 6 is the first of two empirical chapters. It investigates the network governance and structure of the Campinas software network and the innovation activities of local firms during the period 2006-2009. It provides evidence related to the research questions in Group A and Group B, although the chapter addresses the Research Questions Group A. Chapter 7 is the second empirical chapter and investigates the Recife network governance and structure and local firms' innovation activities in the period 2006-2009. It also provides evidence related to both groups of research questions, although it only addresses the Research Questions Group A.

Chapter 8 addresses the Research Questions Group B and discusses the findings presented in Chapters 6 and 7 and derives some conclusions. We describe the contributions of this thesis, and highlight some implications for theory. We discuss some of the limitations of this research and also its level of generalisability. Finally we suggest some policy implications and avenues for future research.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

The topic of this thesis research is public policies aimed at the creation and development of regional network for high-technology activities, network governance and structure, and firm-level innovation in the context of developing countries. This chapter identifies and discusses the related literature in order to identify areas that need further investigation.

The chapter is organised as follows. Section 2.2 discusses the relevance of networks within systems of innovation, addressing especially issues related to the role of networks and technology policy in creating and supporting networks in a dynamic economic context. Section 2.3 discusses the importance of networks for regional development, highlighting the issues of regional networks for economic catching-up, path-rigidity and interactions between new technology-based firms (NTBF) and network actors. Section 2.4 investigates network governance and firm-level innovation and considers issues related to the structure and types of networks and the characteristics of the dyadic ties formed by innovative firms in developing country contexts. Section 2.5 summarises the main findings from this review.

2.2 Networks within systems of innovation

Research on innovation has addressed several issues including: what innovation means (Freeman, 1974), why it is relevant (Freeman, 1987), how it can be fostered and supported (Freeman, 1987; Freeman and Soete, 1997; Pavitt, 1987), who are its performers (NSF, 2010) and how and where it is performed (Edquist, 2004). In this thesis we focus on innovations at firm level, within particular regions. We investigate whether innovations at firm level employ only internal knowledge and information, or also exploit knowledge and information developed externally and accessed by the firm. Our concern is with how this knowledge is used. In discussing how firms access outside knowledge it is useful to introduce the concept of 'networks', which refer to the structure of formal and informal collaborations and common interest relationships among organisations. Section 2.2.1 introduces the relevant concepts and discussions related to networks within systems of innovation. Section 2.2.2 discusses issues related to government intervention in the form of technology policy to support the formation of networks aimed at increasing and improving firm-level innovation (Freeman, 1987).

2.2.1 The role of networks within systems of innovation

It is commonly agreed that the system of innovation consists of interaction among institutions and organisations directly or indirectly involved with technological activities (Freeman, 1987).[5] The system of innovation concept introduced by Freeman has been incorporated into other studies on systems of innovation, such as Lundvall (1992b), Nelson (1993), Edquist (2004), and Lundvall *et al*. (2009a). These authors consider that the components of a system of innovation include: firms, universities, financial organisations, research and development (R&D) organisations, agencies supporting innovation, and government departments (Lundvall, 1992a). There is an assumption of coherence in the relationships among these components aimed at a well functioning system (Edquist, 2004: 187; Nelson and Rosenberg, 1993). Thus, networks and their functioning are core features of a system of innovation.

There is a frequent assumption that developed countries have well developed and extensively inter-connected networks, and that where this is the case, their performance and governance can be assessed. However, in developing country contexts there may be important 'missing links'. Cimoli (2002: 2) notes that networks 'can be considered as a proxy and as an observation unit to understand if systematic linkages and interactions are really diffused or not in the innovation systems'. Firms are the main economic agents benefiting from new knowledge and innovation and are at the core of networks. The system of innovation concept assumes that firms are embedded in a dynamic environment where technological changes are endogenous and, to a certain extent, unpredictable. Therefore, their results cannot be fully foreseen (Nelson and Winter, 1982). This is crucial for understanding how and why networks may emerge and evolve within systems. Their dynamic environment prompts firms constantly to reassess and possibly change their strategies with regard to searching and exploring for new knowledge and information in order to maintain or improve their competitive positions. Search and exploration mechanisms related to innovation performance may be internal or externally

[5] Freeman's concept of system of innovation was strongly inspired by the work of List (1841; quoted by Freeman 1987).

oriented, intra-firm or inter-organisation (Lundvall, 1992a; Nelson and Winter, 1982).

A system of innovation can be defined in different ways that have implications for the investigation of networks. The broad definition of a system of innovation, proposed by Lundvall (1992a: 12) includes 'all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring' and supports the examination of elements that influence the performance of technological activities such as the social, scientific, political, cultural and economic elements within each system. An investigation of systems of innovation based on this broad definition is appropriate to provide the macro-level background in which firms are embedded. However, its capacity to explain firm-level differences in technological and innovative performance is limited since firms are part of the larger system of innovation.

Lundvall (1992a: 12) also proposes a narrower definition of systems of innovation which focuses on organisations that are engaged in knowledge creation and diffusion, that is, organisations involved in searching for and exploring new knowledge, such as innovative firms, R&D organisations, technology institutes and universities. This narrower definition may be more appropriate to investigate systems of innovation at the micro level, and to study organisations and their interactions. It is likely that interactions will differ across firms in clearly observable ways, meaning, effectively, that the value of different elements external to the firm will also vary in ways that can be clearly observed. Empirical investigations of networks of innovators (Freeman, 1991) as a sub-set within systems (Cantner and Graf, 2010), are commonly based on this narrow definition.

In addition to these two definitions of systems of innovation, the literature also emphasises distinct global, national, regional and local perspectives (Edquist, 2004; Freeman, 2002). These approaches are useful to the extent that the relevant institutional interactions take place at the level at which the analysis is conducted. Thus, the national systems of innovation approach has been criticised for failing to consider trans-national structures, such as the scientific research community.

In addition to the types of organisations included and the level of the analysis, the period of analysis is also important. Here, the principal issue is whether the history of institutional development has a persistent influence on the evolution of innovation systems.[6]

There is ongoing debate on whether and how globalisation affects national systems of innovation and on the networks embedded in these systems. Some support the argument that globalisation is leading to increasing codification of previously tacit knowledge and, therefore, that national contexts are becoming less relevant for face-to-face learning interactions (Friedman, 2005). This argument is based on evidence from industries where the codification of knowledge has facilitated technology transfer, such as relatively mature industries (e.g. electronics) where standardisation and codification of the knowledge required for the production process has permitted the relocation of manufacturing. It may apply also to industries whose core components are imported and integrated locally (e.g. integrated circuits prototyped and tested abroad that are used in modular systems) or to the location of call centres for customer support. These examples demonstrate the opportunities for software development in developing countries, where local firms are able to access components critical for software development (e.g. an ERP platform), leading to the 'localisation' of software associated with local value-added activities.[7]

Asheim and Gertler (2004: 310), however, argue that although globalisation is becoming increasingly widespread, national contexts are relevant for examination of national innovation systems.[8] They claim that face-to-face interactions affect trust building and the creation and exchange of knowledge (cognitive proximity), and that smaller scale territories can be more conducive to learning by interacting (Lundvall, 1992b). Asheim and Gertler go further, claiming that regional contexts are especially relevant for the examination of particular systems, and argue for studies of regional systems of innovation; defined by them as 'the institutional infrastructure supporting innovation within the production structure of a region' (Asheim and Gertler, 2004: 299).[9] As already indicated, this claim is valid to the extent that different, smaller regions have heterogeneous institutions and access to institutions.

---

[6] This issue relates to path-rigidity, which is discussed in Section 2.3.

[7] E.g., see Duarte (2003) for empirical evidence of the 'localisation' of globalised software development in a study of 5 Brazilian software firms.

[8] Patel and Pavitt's (1994) analysis confirms these findings, claiming that the local scientific system still plays a major role in the R&D activities performed in each country.

[9] Region has a different meaning in different contexts and different implications in empirical examinations studies. Region can be defined broadly or narrowly. A broad definition of a region is of

The regional systems of innovation approach allows examination of the components of the innovation system (and their interactions) at the meso level, and supersedes the somewhat unrealistic assumption of spatial homogeneity implied by the national systems of innovation perspective (Howells, 1999: 69). Regional systems studies investigate: i) which components of the system are present in the region; ii) whether these components interact, that is, what are the systemic features of the concept, either within the region or with components located outside the region; and iii) whether components present in regional systems are operating appropriately in their self-defined roles. Studies of regional systems of innovation are particularly relevant for the investigation of innovation systems in large countries where economic (as well as social, political and scientific) progress is likely to show disparities among regions (Cassiolato and Lastres, 2003; Cassiolato *et al.*, 2003). Also, different regions often show heterogeneous innovation performance within the same industry. We can compare the performance of the same industry across different regions in the same country and between countries, as well as the performance of different industries in different regions within the same country.

Research on different types of regional systems of innovation (Asheim and Gertler, 2004) shows different levels of importance of networks: i) networks can play a marginal role; ii) networks can be circumscribed within a region and a country; iii) regions may be part of international networks, particularly if the objective is more radical 'global product' innovations.[10] Asheim and Gertler offer two conclusions. First, regions may differ, but the national system of innovation in which they are embedded presents its own specific features, such as institutional set-up, government

---

a sub-continental area such as the European Community, Latin America or East Asia. Freeman (2002) draws on this definition to discuss why East Asian economies were more successful than Latin American economies during the second half of the 20th Century. According to Freeman, East Asian national systems were able to remedy some crucial dysfunctions, which explains their greater success compared the Latin American economies that were unable to tackle the same problems. The narrow definition of region is of a geographical area within a country, state, county or metropolitan area. For instance, Dohse (2000) studies the context of German biotechnology regions in the bidding process for public funding. Some regions comprise a single city, others include the city and its surroundings, which, in turn, may include other cities in the confines of a specific geographical area.

[10] The authors identify 3 types of regional system: i) the territorially embedded regional innovation system, where firms 'base their innovation activity mainly on localized learning processes stimulated by geographical, social and cultural proximity, without much direct interaction with knowledge organizations' (Asheim and Gertler, 2004: 300); ii) the regionally networked innovation system, where 'firms and organizations are still embedded in a specific region and characterized by localized, interactive learning' (Asheim and Gertler, 2004: 301); and iii) the regionalised national innovation system, where parts of its industry and institutional infrastructure are 'more functionally integrated into national or international innovation systems' (Asheim and Gertler, 2004: 302).

intervention and autonomy, economic model (liberal vs coordinated market), labour mobility and education infrastructure, which will influence the region's autonomy, development and performance. Thus, studies of regional systems must consider this national embedding in order to achieve a comprehensive understanding of the performance of the regional system.

Second, timing is very important when comparing regions' innovative and development performance. The different phases of the regions in the industry life cycle must be considered when making regional comparisons because learning, capability building, and the development of new knowledge are long-term, gradual processes. Hence, empirical evidence from an isolated 'snapshot' might lead to the - possibly wrong - conclusion that newer (younger) regions are failing in comparison to more mature (longer established) regions. Timing is especially important when investigating laggard regions, when a macro (national embedding) and meso level (regional systems) analysis combined with the level of regional maturity could explain why some regions are failing to achieve developmental aspirations. In effect, this is a variant of the 'infant industry' argument proposed by List (1841) in the 19th century.

That timing related to the industry life cycle influences firms, networks and innovation systems leads to the concept of sectoral systems of innovation, where the focus is on both innovation performance in different sectors and innovation patterns within and across sectors in which the central actors are private firms (Malerba, 2002).[11] In this perspective, sectors are defined as the 'set of activities that are unified by some related product group for a given or emerging demand and that share some basic knowledge' (Malerba, 2004: 9-10). Each sector presents its own division of labour and knowledge specialisation, involving different creation, use, diffusion and appropriation of knowledge, and learning processes.

The boundaries to the sectoral system of innovation are endogenous, which is an important difference with the regional system of innovation approach where boundaries are most often geographically determined (although particular regions

[11] Breschi and Malerba (1997: 131) state that 'the concept of SIS [sectoral systems of innovation] bears some relationships with taxonomies and categories proposed in the technical change literature …[and] shares many aspects with Pavitt's [1984] well-known taxonomy. In addition, by stressing the role played by sector and technology specific factors, it also has some antecedents in the notions of technological trajectories and paradigms'.

can be central or peripheral at any moment in time). The definition of region can be arbitrary and may follow conventional criteria (Edquist, 2004).[12] In terms of both timing and definition, the flexibility implied by adopting region as the unit of analysis in turn implies the existence of some level of endogeneity in its definition. The concepts of sectoral and regional systems of innovation overlap in their understanding that learning, cooperation, competition and geographical areas are relevant, since, in some sectors, firms are concentrated in particular regions, which determines the different levels of geographical concentration of innovators (Breschi and Malerba, 1997: 139). The geographical distribution of innovators is related to the sector's opportunities, appropriability and cumulative knowledge conditions, which, in some industries, are associated also with the geographical localisation of specialised knowledge and technology suppliers.

One of the most successful cases of a sectoral and regional system is the semiconductor industry in Silicon Valley in the USA, where close geographical interactions among knowledge suppliers, technology organisations, firms, the labour force, customers and product suppliers benefited from industrial knowledge cumulativeness in the region, which attracted innovators that contributed to the accumulation of specialist knowledge and the continuous virtuous cycle set up in the region (Castilla *et al.*, 2000; Kenney, 2000; Saxenian, 1994).[13] The Italian industrial district of Modena, which specialises in knitwear, is another success story (Lazerson, 1993).

The type of knowledge required for the development of each sector determines firms' needs for external knowledge or information, which can be addressed through creation of a new or participation in an existing network.[14] Networks may emerge in uncertain and changing environments as a result of differences (not similarities) among agents that are seeking complementary knowledge, capabilities and specializations (Malerba, 2004: 26). For example, high-technology sectors are more likely to perform in-house R&D and use scientific knowledge, which may demand close interaction between the firms and knowledge producers (e.g. universities).

[12] Edquist (2004) provides the example of Germany, where the 'Länder' is an appropriate unit of analysis, and claims that 'the choice of approach may not only be a question of size of the country, but also whether it is federally organized or not' (Edquist, 2004: 200).

[13] These authors point out that one of the most important reasons for the success of the region is the loyalty of its labour to the region rather than to firms and find that the rate of labour mobility among firms is extremely high, allowing the transfer of both codified and tacit knowledge.

[14] Malerba (2004) defines a network as interaction among different actors.

Conversely, firms performing in low-technology sectors may rely more on external sources of innovation than on in-house R&D and be less likely to engage with science or knowledge supplier organisations. The former would be categorised as science-based and the latter as supplier-dominated in Pavitt's (Pavitt, 1984) taxonomy.

Von Tunzelmann and Acha (2006), however, argue that low-technology sectors may be close to and sometimes integrated with recently developed technologies which may be science intensive, blurring the division between high-technology and low-technology sectors.[15] Similarly, Pérez (2008) proposes a new strategy to support the economic catching-up of developing countries in Latin America, claiming that a new and complementary exploitation of these countries' natural resources is required to achieve dynamic and sustainable economic growth. She claims that the exploitation of natural resources should relate to the processing industry in high added-value, low-volume niches (which differs from the view that natural resources are merely commodities). Since resource-intensive sectors rely heavily on supplier-dominated innovations based on the employment of capital equipment (Pavitt, 1984), the exploitation of the natural resources in developing countries as proposed by Pérez, may be limited by the innovations introduced by capital equipment suppliers.

The arguments put forward by von Tunzelmann and Acha, and Pérez highlights the role of networks in developing countries, suggesting that they combine new types of complementary knowledge which may play crucial roles in industrial development and technological catch-up. However, there is insufficient evidence about what drives innovating firms in developing countries to network, and on the roles that networks perform within their systems of innovation. The above issue raise questions about the role of government intervention through technology policy to support the creation of networks; this is discussed in the next section.

2.2.2 Technology policy and networks

Technology policy addresses two intertwined issues: i) the role of the state and government intervention in the economy to promote social welfare (Block, 1994;

[15] E.g., margarine production, from the perspective of its general formulation, is a low-technology activity of the food industry; however, the leading firms have incorporated ingredients based on frontier scientific knowledge to differentiate their products (e.g. Unilever and plant sterols; de Campos, 2006). As discussed in Section 2.3.1 this type of development could be important for developing countries.

Steinmueller, 2010; Stiglitz, 2002); and ii) technology defined as a partly public good, whose role in economic activities related to creation, development and diffusion of technology requires government intervention (Dasgupta, 1987; Ergas, 1987; Mowery, 1995; Storper, 1995). The first relates mainly to the question of whether government intervention is necessary; advocates of markets argue that market equilibrium and profit incentives are sufficient to solve most problems of resource allocation efficiently, with the exception of the provision of public-goods (i.e. non-rival and non-excludable goods such as defence, utilities, education and health services) where government intervention is justified. This intervention is based on the assumption that the public sector is an important, primary public-good customer (Steinmueller, 2010) and the positive externalities from mixed (i.e. partly-public and partly private) goods are constrained by the distribution of income among consumers rendering the level of private consumption below optimal, which does not provide sufficient incentive for for-profit organisations to invest (Block, 1994: 692).[16] The second aspect relates to the fact that technology involves both the knowledge embodied in machines and person-embodied codified and tacit knowledge about the development, operation of and improvement to machines (Pavitt, 1987). Although technological knowledge is different from information,[17] its informational content may allow technological knowledge spillovers within the economy, making technology a partly public good (Mowery, 1995: 519; Storper, 1995).[18]

Advocates of government intervention, however, argue that market failures are frequent and should be monitored (Boyer, 1997) and that the state has the capability to adjust or correct market imperfections through interventions. The role of the state and government intervention to improve social welfare is influenced by whether economic actors are likely to respond to policy interventions, especially if they have a history and experience of the economic setting which might affect their response to government attempts to intervene, and the capability of the state to assess whether

[16] E.g., Block (1994: 693) points out that this argument justifies state provision of public education.

[17] If technology equated with information, innovation would be expensive, but not its imitation; however, they have been shown not to be equivalent (Pavitt, 1987); firms need to develop a minimum level of absorptive capacity in order to de-codify and replicate external knowledge developed by competitors (Cohen and Levinthal, 1990).

[18] The informational content also shows the feature of the technological knowledge it embodies (and possibly transfers) through labour mobility, which reinforces the important role of networks for innovation activities.

strategic alliances among economic actors should be fostered or left to emerge as a consequence of self-interest. This capability relates to governance mechanisms (such as regulation) implemented by the state to foster or prevent formal collaboration among the economic actors.[19]

Among the sources of market failure, technological knowledge spillovers can lead to negative externalities such as free-riding by rivals on investments made for innovation, which results in incomplete appropriability of the profit generated by the private production of new technological knowledge (Dasgupta, 1987) and, hence, under-compensation of the cost of investment (Steinmueller, 2010). Also, technological knowledge spillovers potentially can undermine market competition through the imposition of intellectual property rights (e.g. patents), and investments in technological knowledge are inherently risky; a high proportion of technological development is not diffused because of the risk of social or economic rejection (Pavitt, 1987: 182). Thus, to address the issues of appropriability and risk, government intervention related to technological activities may be necessary, and may be justified from a social welfare perspective.

The market failure and partly-public good characteristic of technology supports the implementation of government technology policy, however it overlooks issues related to the areas/sectors where government intervention would be legitimate and effective, that is, should the government intervene only in sectors related to national social interests (such as military defence) or should it intervene for commercial reasons (Lundvall and Borrás, 2005: 608-609).[20] The systems of innovation argument would be that support for technological activities is crucial for socio-economic development (Freeman, 1987) and, therefore, that technology policy and government intervention play major roles in the economy, to further national social interests and also commercial sectors (Ergas, 1987), especially those involving

[19] E.g., Jorde and Teece (1989) claim that anti-trust regulations imposed by the US government prevented the emergence of strategic alliances in US high-technology industries at the end of the 1980s. According to the authors, US over regulated antitrust laws prevented the formation of strategic alliances among small firms to invest in cooperative research and development that would benefit the allied firms. Shapiro and Willig (1990) contest Jorde and Teece’s argument, especially in the case of antitrust laws governing horizontal joint ventures in the USA. In contrast to Jorde and Teece, Shapiro and Willig argue that there is no consistent evidence that antitrust policies prevented cooperation among American firms or stifled their innovation and international competitiveness. See also Brodley (1990) for a more detailed discussion on this issue.

[20] Nelson (1977) analyses public policies in more general terms, claiming that science and technology policies should address social priorities as well as national interests.

increasing economic returns and positive spillover effects. For instance, the importance of state investment in high-technology industries (e.g. ICT related industries) justifies government intervention because of the pervasiveness of these industries and their high potential for economic outcomes that will benefit a large share of society. State regulation and support are particularly relevant in industries that exploit inputs produced by subsidised sectors, for example the downstream application of 'green' technologies. Larger development objectives might justify temporary subsidies (especially in the case of 'infant industries' capable of maturing to become independent). Where market failures are seen as persistent (e.g. the case of very long-term investment in 'transition' as in the case of reducing carbon dependence), subsidies may need to apply for several decades.

The discussion above calls for a definition of technology policy and some clarifications about how it is channelled, especially with regard to the formation of networks. Mowery (1995: 514 - emphasis added) defines technology policy 'as policies that are *intended* to influence the decisions of firms to develop, commercialize or adopt new technologies'.[21] Technology policy is applied using different mechanisms, to improve the institutional and economic settings such that firms, the main drivers of technical change and economic development (Freeman, 1987), are encouraged to invest in innovation and technological activities. Technology policy is related to networks through their roles within government and within the economy.

Networks within government are related to several issues. They are involved in the creation of public bureaux and the bureaucratic infrastructures that are designed to support the decisions of policy makers. Bureaucracy is justified by the argument that policy makers are not able to access all the information available about their operations and also do not have the capacity to filter out which information is more

[21] There is no consensus in the literature on a definition of technology policy, however, there is some agreement that science and technology policy addresses different economic resources. Lundvall and Borrás (2005) differentiate between technology policy, science policy and innovation policy. According to them: i) technology policy 'refers to policies that focus on technologies and sectors' Lundvall and Borrás, 2005: 607); ii) science policy concerns the sufficient allocation of resources 'to science, to distribute them wisely between activities, to make sure that resources are used efficiently and contribute to social welfare' (Lundvall and Borrás, 2005: 605); and iii) that 'innovation policy lies between initiatives aiming at promoting innovation within the institutional context and those aiming at changing in the institutional context in order to promote innovation' (Lundvall and Borrás, 2005: 612-613).

important and more reliable for their decisions (Downs, 1964).[22] Therefore, it is necessary to create support agencies and bureaux that can develop expertise and knowledge in particular fields and can be consulted by policy makers in their decision making processes. These agencies and bureaux, in practice, are often organised as networks rather than hierarchies – that is, their remits overlap and their 'chains of command' flow only nominally from some higher authority. Networks within government also relate to the interaction between government officers and third-party actors that are a part of their professional (formal and informal) networks. For instance, government officers may be able to consult and bring together actors from academia and industry with different knowledge about a specific subject. Working together allows the combination of this fragmented knowledge to further technological developments in a particular industry. Fuchs (2010), for example, examines the case of the US Defense Advanced Research Projects Agency in the period 1992-2008 and shows that the role played by its programme managers' networks were crucial for supporting the identification and development of new technologies for the US defence industry. Fuchs (2010: 1145-1146) highlights also the role of government officers' networks as a new form of technology policy, claiming that:

> embedded government agents re-architect social networks among researchers so as to identify and influence new technology directions (…) these agents do not give way to the invisible hand of markets nor do they step in with top-down bureaucracy to 'pick technology winners'. Instead, they are in constant contact with the research community, understanding emerging themes, matching these emerging themes to military needs, betting on the right people, connecting disconnected communities, standing up competing technologies against each other, and maintaining that birds-eye perspective critical to integrating disparate activities across our national innovation ecosystem.

Finally, networks within government may be an emergent property of particular policies. This is observable as a co-evolutionary development stemming from the greater role of autonomous and semi-autonomous private entities that deliver public services on behalf of government. For instance, Rhodes (2007) explains that the more market-oriented approach of the British government since the 1980s was aimed at increasing competition among autonomous public service providers. In practice, however, it resulted in the fragmentation of public service delivery systems, forced

[22] See Downs (1964) for an elucidation of the benefits and possible shortcoming of bureaucracy.

autonomous organisations to cooperate and multiplied the number of networks (Rhodes, 2007: 1245).[23] More in depth discussion of the role of networks within government is beyond the scope of this thesis; here, we concentrate on the role of networks in the economy, and especially why technology policy aims, amongst others things, to support and foster the creation and development of networks.

Networks within the *economy* more generally, play an important role because they provide the possibility to investigate interactions among economic actors that are not 'completely' based on formal contracts or obligations (networks are an intermediate form between market and hierarchy; Powell, 1990). Networks 'breed trustworthy relations' among economic actors (Giuliani, 2010: 264; Granovetter, 1973, 1985), potentially reducing transaction costs and favouring the creation and diffusion of knowledge.[24] Therefore, networks are often seen as a positive source of spillovers. However, the costs of networking can outweigh the benefits when relationships are poorly coordinated, the costs of forming and finishing alliances can be difficult or expensive, 'thus once established, there may be reluctance to disband them' (Powell and Grodal, 2005: 78), and networks also may trigger collusion among a small number of actors, which can lead to the formation of cartels and exclude competitive entry.[25]

Since the 1990s, the relevance of networks has increased due to the emergence of successful clusters or districts associated with the presence of networks (Giuliani, 2010: 261). The way that networks are structured, especially in developing countries, has been tackled by a few scholars including Dantas and Bell (2009) who investigate the Brazilian oil industry, Dodgson *et al.* (2008) who investigate the Taiwanese biotechnology industry, Giuliani (2010) who investigates the wine industry in Chile and Italy, Kim and von Tunzelmann (1998) who investigated the Taiwanese ICT industry, Ramirez and Dickenson (2010) who investigated the ICT industry in China, and Perini (2009) who investigates knowledge networks in the Brazilian ICT sector.

---

[23] It is assumed that any discussion of government action, in the main, would address political hierarchy as a mode of governance. For an elaboration of this issue and how the role of networks has increased in relation to delivery of government services since the 1980s, see Bevir and Rhodes (2001) and Rhodes (2007).

[24] See Callon (1999) for a more general claim that actors do not interact based on arm's length relationships, an argument that is central to Walrasian and other neo-classical approaches to understanding markets as auctions.

[25] E.g., Shapiro and Willig (1990) and Brodley (1990) discuss the benefits and problems related to inter-firm cooperation through joint ventures, mainly addressing the antitrust regulatory regime in the US.

However, most studies of networks concentrate on developed economies, for example (among others), Ahuja (2000), who investigate the chemical industry in Japan, Western Europe and the US, Cantner and Graf (2010), who investigate the network of innovators in Jena, Germany, Cooke and de Laurentis (2010), who investigate the UK ICT industry, Fuchs (2010), who investigates the US defence industry, Grasenick *et al.* (2008), who investigate knowledge intensive networks in the Styria region in Austria, Herrigel (1993), who investigates the Baden-Württemberg region in Germany, Lazerson (1993), who investigates the Modena region in Italy; Nohria (1992), who investigates Route 128 in the US East region; Saxenian (1994), Castilla *et al.* (2000) and Kenney (2000), who investigate the US semiconductor industry and Uzzi (1997), who investigates the apparel industry in the New York region of the US.

Following the assumption of the system of innovation that local contexts play an important role in the creation and diffusion of knowledge, technology and innovation, we find that networks can be contextualised in particular socio-economic and geographical settings and may differ with regard to, among other things, their emergence, evolution and structure.[26] Although networks differ, Grabher and Powell (2004) claim that it is possible to recognise the types of networks that may emerge through the performance of economic actors operating under similar conditions. They group networks into four types: i) informal networks (based on inter-personal ties); ii) project networks (to fulfil specific tasks, limited in time and involving formal and informal ties); iii) regional networks (trust and reputation are key assets and division of labour is common); and iv) business networks (which are more 'strategic and orchestrated', in which power plays an important role in inter and intra-organisational ties).[27] Although this typology may be useful for empirical investigation of networks, there is no reason to believe that they do not intermingle (Granovetter, 1994).[28] In addition, networks can be the result of a purpose (i.e. be strategically created) or may be emergent (i.e. based on incidental interactions).

[26] The Social Network Analysis methodology investigates the structure of networks. See Scott (1991) for a comprehensive explanation of this.

[27] E.g, Granovetter (1973) examines the role of informal network in labour mobility in the US, Castilla *et al*. (2000) examine the regional network in the Silicon Valley region in the US, and Granovetter (1994) examines business intra-networks.

[28] Section 2.4 develops the issues of networks as a mode of governance.

In many cases it appears that government actions play an incidental facilitating role in the formation and maintenance of networks. For example, one of the main technology policy channels supports the formation of networks by defining and funding institutions that develop new scientific or technological activities, and may also support the training of skilled labour (Mowery, 1995). This may foster the formation of informal networks among actors with a common professional background, affording individuals and organisations the opportunity to engage in scientific and technological development communities (Salter and Martin, 2001). This type of policy has proved an important mechanism to support public-private sector collaboration (Faulkner and Senker, 1995) and the establishment of ongoing networks of participants. For instance, recipients of government funding for scientific training (university-trained scientists and engineers) may engage with the private sector (through employment or entrepreneurship) and create ties with former students or professors, based in their common understandings of particular problems (Pavitt, 1987: 184). Ties among entrepreneurs will be formed and probably maintained over time, especially if the entrepreneurs engage in active acquisition of new knowledge to maintain their competitive positions and if training institutions are open to collaborations with the private sector.[29]

A second, more direct way to influence the formation and maintenance of networks is to impose new regulations to improve relations among the actors and agents involved in technological activities and innovation. An example here is the European Commission Sixth Framework Programme ‘Network of Excellence’ which provided funding for networks as infrastructures to which more specific project funding would be directed on a preferential basis (David and Keely, 2003). Apart from the relatively rare instances of policies explicitly directed to network formation, such as the Networks of Excellence funding as part of the European Commission Framework Programme and the Softex programme examined in this thesis, the formation of networks can be related to government funding programmes requiring certain forms of collaboration to promote coordination among actors. For instance, Steinmueller (2010: 1192) refers to the ‘thematic funding’ design and as describing ‘a wide range of programs that involve the predefinition of themes under which eligible candidates

[29] The case of the semiconductor industry in Silicon Valley investigated by Saxenian (1994) is a clear example of the formation of both types of networks (formal and informal) in the region; Stanford University was shown to play a crucial role in supporting entrepreneurship.

are invited to propose specific programs of research'. Requirements often include project teams including members from industry and academia. Thus, thematic funding may support the formation of networks in two ways. Firstly, the thematic funding call may require the participation of several actors in the application processes and the creation of formal collaborations (e.g., between firms and universities). Secondly, the themes per se may involve sophisticated scientific knowledge that requires firms to engage (at least informally) with scientific or technological organisations to produce sufficiently detailed grant proposals and to increase the chances of funding being awarded.

More fundamental science and technology policies also promote the formation of networks, and include, among other things, actions related to basic research, higher education, public procurement, subsidies and tax reductions (Lundvall and Borrás, 2005; Mowery, 1995). These types of policies support network formation more indirectly. For example, large scale education policies that include scientific and technical training aimed at the development of a specific technology, may foster the formation of informal or regional networks. The former are based on the assumption that informal networks among actors with similar professional backgrounds are common (following the rationale described above). Regional networks may emerge when government strategy is directed to a particular region or confined to scientific and technical training institutions in a specific geographical area (e.g. to promote the establishment and growth of technology parks). The assumption is that the presence of crucial actors with a developed capability to advance the technological development of a particular industry or to handle changes to the technological paradigm, may benefit from spillovers of knowledge from other actors in the region (not least through labour mobility within a delimited geographical area).

Other indirect technology policies may support the formation of networks, including actions to improve basic education and training standards,[30] and promote competition policy and public investment.[31] Such policies support the aims and roles of public organisations. Both the assignment of new missions to existing public organisations

[30] For instance, Ergas (1987) discussed the importance of basic education and training for the technological development of countries that followed a 'diffusion-oriented' technology policy, such as Germany, Switzerland and Sweden (as opposed to 'mission-oriented' technology policy countries, such as the UK, USA and France).

[31] Mowery (1995: 539) stated that technology policy does not conventionally include competition amongst it instruments. However, competition has proved to be relevant to assure the enhancement of national innovation performances, and therefore may be included as a technology policy instrument.

or the creation of new organisations to correct dysfunctions within innovation systems (Steinmueller, 2010), may support network formation by establishing or increasing the interactions between the public and private sectors. These may include: i) exemptions on private sector involvement; ii) support for academic engagement with the private sector; and iii) sharing of intellectual property revenues among organisations, departments and individuals to recognise the contributions of each party. In this context, there will be a higher probability of formal network formation through consortia or engagement in the co-development of scientific or technological activities. Also, the assignment of new missions to existing public organisations might indirectly support the formation of interactions among private actors.

In addition to government-led interventions, technology policy may also involve bottom-up arrangements to improve coordination among economic actors by: i) supporting the emergence of or improvement to institutions that develop any kinds of scientific or technological activities; ii) negotiating new regulations in order to improve the relations among the actors involved in technological activities and innovation; iii) negotiating new import and export laws; and iv) encouraging the establishment of institutions that contribute to the innovation process. As discussed in Chapter 1, Section 1.1, bottom-up arrangements increase the likelihood of the engagement of emergent networks. This is not to say that such networks are based on balanced relationships among actors, bottom-up arrangements may call for coordination under hierarchical as opposed to heterarchical arrangements in which the power among actors tends to be more balanced. Hierarchies can be expected to emerge when particular actors have higher reputations in their milieux (compared to their peers) and better access to government representatives resulting in a higher probability of individual and collective requests being considered and granted.[32]

A discussion of technology policy supporting the formation of networks requires examination of the following issues: i) what technologies and sectors should be prioritised (Freeman and Soete, 1997: 385), that is, should government support or invest in industries that are entirely new - to both the country and the world, or only those that are new to the country; in either case, there is likely to be a need for long-term capability building to create scientific and technological knowledge consistent

[32] Industry associations are one example of the actors that may perform these roles.

with the more general infant industry argument; ii) should government prioritise high-technology or low-technology industries for investment bearing in mind that the boundaries between these industries is sometimes blurred; iii) which technological stage(s) should be supported, that is, there is a need to assess the trade-off between investing in industries during their early or their more mature stages and the various risks and different appropriation of profits (Pérez, 2001); iv) whether industries should be supported in terms of competition, promotion or a combination of the two; and v) whether the government agenda should include regional industry developments since, historically, industrial activities tend to be concentrated in geographical areas and geographic proximity can support formal and informal interactions among actors pursuing the development of similar or complementary technological knowledge (Boschma, 2005; Boschma and Martin, 2010b; Cooke, 2001; Cooke and de Laurentis, 2010; Storper, 1995; Storper and Harrison, 1991).[33]

The above discussion provides a theoretical view of how networks may be fostered and supported by government technology policy. However, the implementation of policy is not straightforward, and, as argued in the systems of innovation approach, differences in the economic and social settings may influence its implementation and results (Dasgupta, 1987). In addition, differences in the characteristics of sectors and regions may influence the success of technology policies. The particularities of the technologies (sector related) and local contexts (region related) may explain why successful experience cannot easily be replicated. Section 2.3 addresses some of these issues with a particular focus on the importance of networks for regional development and economic catching-up.

2.3 Regional development and networks

The importance of networks for regional development and economic catching-up is discussed in the context of path rigidity and institutional history which are crucial for understanding how regions evolve (Section 2.3.1). We discuss the relevance of networking activities involving NTBF, especially in the software industry (Section 2.3.2).

[33] The identification of these issues is based on the discussion in Lundvall and Borrás (2005) related to economic catching-up, which is examined in more detail in Section 2.3.

2.3.1 Regional networks and economic catching-up

Regional development and regional networks are informed by the understanding that technical progress is an endogenous process that develops in the course of economic growth (Freeman and Soete, 1997).[34] This assumption has implications for examination of the emergence and development of industrial regions, and for the catching-up process in different regions. The issues involved relate directly to the concept of path dependence at whose core is the argument that past economic and technological choices influence present results, and that 'history matters' in the evolution of organisations and institutions (David, 1994: 208).[35] The concept of path dependence is particularly relevant for the understanding of how networks and regions evolve. It is necessary to consider the process by which regional networks can become locked into certain paths through a process of self-reinforcement or released from a previous institutional, economic or technological path. The concept of path dependence and the knowledge that history matters are crucial for an investigation of networks in developing country economies, where networks commonly are embedded in rather negative social, economic, institutional and technological contexts that are associated with social inequalities, economic vulnerability to external economic shocks, lack of skilled human resources and obsolete technologies. This raises questions about how laggard regions can break free of their lock-in to negative paths, which might be a requirement for socio, economic and technological catching-up.

According to the path dependence theory, a change of paths is triggered by an external shock and the costs involved in disturbing the equilibrium associated with lock-in may produce a worsening of the economic position. In some cases, these costs may be so substantial that they prevent the transition to other paths. The costs of switching to a new path can be a major constraint on developing country regions. Although managerial decision-making process tend to maintain paths (i.e., path rigidity), internal or external intervention may enable path switching. The use of a

[34] Freeman and Soete (1997, Ch. 13) provide a detailed historical discussion of the assumptions about and shortcomings of old and new growth models. In the former technical progress is treated as an exogenous variable and in the latter it is an endogenous variable. Further exploration of this topic is beyond the scope of the literature review in this chapter.

[35] It is important to point out that path dependence and history are not equivalents. History matters because of the cumulativeness and directionality of the choices made in past events; path dependence occurs when it is impossible to achieve a particular position due to the accumulation of experience along a particular 'path' or direction.

framework that combines exogenous and endogenous incentives for a change in direction increases the scope of technology policy formulation and implementation. Regions set on a particular path, may offer scope for government intervention in the form of technology policy and the potential for a change in direction through changes to supply or demand policy (Steinmueller, 2010). However, there are no guarantees that these interventions will be effective.

Contributions to the path dependence literature from such authors as Martin and Sunley (2006; and 2010) and Boschma and Martin (2010b), who are not economists, use the term path dependence to refer to situations characterised by path rigidities. This could apply to some Brazilian regional and industrial development experience because government technology policy for some Brazilian regions has been aimed at the creation or re-creation of new paths.[36]

However, these studies tend to skim over investigation of the role of nodes in networks (i.e. how dyadic ties are formed).[37] Empirical evidence could provide explanatory variables for understanding whether and how self-reinforcing, negative paths may be changed through endogenous or exogenous processes.

Path rigidity is directly related to technological catching-up at regional and country level, because changes to paths may support the emergence of new opportunities for laggard economies to improve their technological activities and catch-up to the leading economies. At country level, development paths are associated also with changes in technological paradigms (Dosi, 1982),[38] such as the ICT revolution (Pérez, 2001). ICT has accelerated economic globalisation and influenced the development of networks within innovation systems, and economic actors that are more knowledgeable about their own and other networks and systems, which in theory increases their potential to access other actors. This applies to networks in developing countries and potentially increases the access to and engagement of developing country actors with new knowledge in new technologies. However, access to new knowledge does not necessarily include the 'know-how' required to use it.

[36] Chs 4, 6 and 7 examine some of these experiences in some depth.
[37] E.g., recent studies on Brazilian innovative regions, such as those in Cassiolato *et al.* (2008a), are not included in the in-depth investigation of dyadic ties within networks.
[38] Dosi (1982:152) defines a 'technological paradigm' as a 'model' and a 'pattern of solution of *selected* technological problems based on *selected* principles derived from natural sciences and on *selected* material technologies' (emphasis in original).

An examination of regional path rigidity and technological catching-up is particularly relevant in the case of large countries. First, because there are likely to be more regional disparities (as discussed above), and different regions are likely to have developed along different paths. Second, because industries are often concentrated in geographical regions (Asheim and Gertler, 2004; Boschma and Martin, 2010b; Cooke, 2001; Dohse, 2000; Giuliani, 2010; Markusen, 1996; Saxenian, 1994; Storper, 1995), and use different mechanisms to develop their technological activities (Breschi and Malerba, 1997; Malerba, 2002, 2004; Pavitt, 1984; Steinmueller, 2004).

So how can networks embedded in regions support technological catching-up within a particular path? Since networks involve collaboration (as discussed above), we need to investigate whether and how support for collaboration among regional firms might improve their technological activities; such improvement is expected *ex-ante* to increase firm competitiveness and the process of catch-up with competitors.

The case of Japan's technological catching-up process, especially after World War II, highlights the importance given to networks by Japan's Ministry of International Trade and Industry (MITI). The formulation of industrial policy involved frequent discussion between MITI members and industry scientists and technologists, aimed at supporting and improving policy and its implementation (Evans, 1995: 49; Freeman, 1987: 36). Also, MITI and Japanese industry associations pursued systematic efforts to 'upgrade' local capabilities through the formation of learning networks, with a specific focus on developing technology domestically, with the aim of reducing dependence on foreign technologies (Okimoto, 1989).

The cases of the Taiwan's IT and biotechnology industries investigated in Dodgson *et al.* (2008) demonstrate the importance given by national governments to supporting the creation of local (purposive) networks and the creation of science parks to nurture IT and biotechnology developments. These efforts were aimed at changing the 'imitation' path to an 'innovation' path. The interactions between firms and knowledge suppliers (such as universities and technology centres), and local venture capitalists were very important for the local development of these industries, and the eventual catching-up by Taiwan's IT industry.[39]

The networks described above were facilitated by government through institutional changes addressing the needs of the two industries, in the form of adapted rather than horizontally implemented institutional support. In the case of the Taiwanese IT industry, government supported interaction involving local firms and MNCs, aimed at diffusing existing knowledge. In the case of the biotechnology firms, government fostered interactions between firms and local knowledge suppliers to create new local knowledge. Adaptation of policies to fit different industry developments shows that the Taiwanese government recognised that industries differ and no 'one model fits all'; it was a recognition that different paths (in this case technological paths) require different monitoring and support. The lessons from experience in Japan and Taiwan are that networks can lead to technological development, but that policy makers need to consider the technological and institutional paths within industries so that more appropriate networks emerge, the costs of changes to rigid paths can be more accurately assessed and technological catch-up is achieved. Both these cases seem to be exceptions rather than the rules, which implies further investigation is needed into whether this process can be replicated in other developing countries and with what results.

Another aspect of networks and catching-up is how successful experience can be replicated, and especially in developing countries which often try to replicate developed economy examples with the expectation of similarly successful results. The systems of innovation approach states that systems differ and, therefore, that national governments need to be cautious about their choice of supporting mechanisms aimed at technological development, especially in developing countries where systems may not be complete (i.e. may be missing some components), or may be dysfunctional (i.e. their components do not perform as expected) (Bell and Pavitt, 1993; Cassiolato *et al.*, 2003; Lastres and Cassiolato, 2001). Whilst, the replication of experience is associated with uncertain results, this does not mean that regions and countries cannot learn from the experience of others. Understanding how firms combine different knowledge, and their ability to engage in networks is required for

[39] Although the share of venture capital investment is larger in the IT industry than in the biotechnology industry.

the successful replication of experience in other contexts. Section 2.3.2 discusses this in relation to software firms.

2.3.2 NTBF and networks

This section aims to discuss how NTBF combine different knowledge for the development and commercialisation of their products or services, that is, whether NTBF employ knowledge that is developed internally or externally, or a combination of both (when they assemble and integrate knowledge from various sources). We discuss the motivations for NTBF network activity focusing on the case of software firms.

The development of software products and services is part of a wide range of development activities that include systems, packaged applications and customised applications (Steinmueller, 2004). The software industry is highly creative, as noted by Brooks Jr (1995: 7), and software programming relates to 'the joy of always learning, which springs from the non-repeating nature of the task. In one way or another, the problem is ever new, and its solver learns something: sometimes practical, sometimes theoretical and sometimes both'. Software development involves the systematic planning of the division of labour (Brooks Jr., 1995), systematic documentation and training (Cusumano and Selby, 1995),[40] and well established communication and coordination among software programmers (Heeks *et al.*, 2001). Each activity of software systems and packaged and customised applications, varies in its complexity and may demand different types of scientific, technological and commercial knowledge, requiring 'firms to mix internal competencies, knowledge and experience with external sources of knowledge' (Grimaldi and Torrisi, 2001: 1428) through the creation of external ties with other organisations such as universities, suppliers, competitors and users. Although there may be patterns of relationships among software firms or between software firms and network actors, the role of networks may differ for the individual firms in the software industry.

[40] Cusumano and Selby (1995) provide a detailed investigation of how Microsoft improved its software development processes adjusting and adopting internal procedures, over the years, aimed at supporting its accelerated growth, which coincided with a dynamic technological evolution within the software industry.

The international software industry is highly concentrated, especially in the development of packaged and platform applications, which are mainly dominated by US software suppliers (Steinmueller, 2004). Most software firms innovate by differentiating and customising their products to particular application contexts, which often involves close relationships with customers (users). Software developments also frequently require knowledge that is accessed through networking activities, for instance, with supplier firms, complementary firms, university researchers and competitors.

Grimaldi and Torrisi (2001) in an investigation of formal external ties among Italian software firms, find that ties can be classified as research-oriented or market-oriented. Research-oriented ties may involve formal links with competitors (e.g. through joint R&D agreements) or software firms that develop complementary technologies. Market-oriented ties usually involve firms that perform in different stages of a technological process (e.g. systems suppliers) or in different regional markets and are designed to gain access to specialised commercial assets, service expertise and new markets (Grimaldi and Torrisi, 2001: 1431). Market-oriented ties can include the use of well-established systems or platforms that benefit from the network externalities related to the use of well-diffused technologies developed by platform providers and which can be customised (often as a value-added computer service activity) to particular users (Shapiro and Varian, 1999).

The discussion above suggests that although software development is strongly related to the employment by trained developers of internal knowledge gained through study and experience, networking activities are also required. In this thesis we are particularly interested in the relations between firms and supporting organisations that are part of a network that also includes customers, and investigating networks created by firms that develop software as a business. Section 2.3.1 suggested that micro level investigation of networks, that is, of the dyadic ties between the nodes in a network, is relevant to explain the structure and evolution of networks that might explain how paths change or are changed. We investigate this in Section 2.4.

2.4 Network governance and structure, and firm-level innovation in a developing country context

Section 2.4.1 reviews the literature on network governance and structure and discusses the importance of dyadic ties and control mechanisms within networks. Section 2.4.2 addresses the main concepts related to firm-level innovation and especially networks embedded in developing countries.

2.4.1 Network governance and structure

The issue of network governance concerns the relation between the structure and the functions of networks. Governance can be seen as purpose-related in the deliberate effort to establish and manage a network, for example aimed at achieving market leadership for its members. Governance can emerge in a self-organising fashion, for example through the emergence of 'anchor' actors within the network whose influence is based on long-term trust relationships with other network actors. Network governance is mostly confined to organisation studies where the main units of analysis are i) coordination mechanisms within networks and ii) the existence, nature and extent of dyadic ties among network nodes (Provan and Kenis, 2008). The definition of 'network governance' varies; it often includes a bias towards investigation of one or other of the units of analysis described above (i.e. purpose as a constituting rationale for establishment or management, or purpose as an emergent property of the network) rather than considering both within a single framework. The definition of network governance related to intra or inter-network structure and functions is somewhat arbitrary (as noted by Jones *et al.*, 1997).[41] However, all the definitions proposed assume that the actors are neither isolated from one another nor take decisions based on arm's length relationships (Callon, 1999). Networks are considered to be embedded in social and economic settings that are likely to influence the actors economic decisions and formation of ties (Granovetter, 1985, 1992).[42]

---

[41] Jones *et al.* (1997: 915) provide a table showing that inter-organisation networks, alliance capitalism, business groups and social networks are terms used by different authors who examine network governance issues.

[42] According to Granovetter (1992: 33; emphasis in original) 'embeddedness refers to the fact that economic action and outcomes, like all social action and outcomes, are affected by actors' dyadic (pairwise) relations *and* by the structure of the overall network of relations'.

As mentioned above, the role of networks in fostering development is increasingly acknowledged, in part because networks are an important complement to markets by facilitating exchanges of information on current and future opportunities and developments governing the planning and operational decisions of upstream firms in current production processes. Firms' engagement in networks brings benefits in the form of externalities resulting from knowledge about the plans of other firms. This knowledge is relevant for development, because the effects of coordination externalities help to overcome information asymmetries.

In this thesis, network governance and structure is related to *the inter-organisational coordination exerted in a particular institutional setting*. Jones *et al.* (1997: 913) define network governance as inter-firm coordination. We extend this to include all organisations (for profit and non-profit) in the network. We understand coordination as occurring when two (or more) network actors have a common goal and establish a tie in order to pursue it (Bevir, 2009: 57). This definition encompasses a more comprehensive understanding of network governance compared to studies that investigate only dyadic ties and consider governance as an emergent or collateral property of a network. It also encompasses the micro and the macro dimensions of networks,[43] which are overlooked by most network governance studies (Provan and Kenis, 2008).[44]

Micro level investigation of networks examines the creation, nature and strength of dyadic ties. The work developed by Granovetter (1973: 1361) on the strength of ties, defined by him as 'a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie', is a major contribution to the investigation of networks that has been applied frequently.[45] Granovetter (1973) defines a strong tie as a direct connection between two actors that is based on trust, reputation and a long-term relationship, and is difficult to break and likely to continue through time. He defines

[43] Studies of dyadic ties provide a micro analysis of the network, referred to by Jones *et al.* (1997) as relational embeddedness and by Provan and Kenis (2008) as the analytical approach. Studies of network control mechanisms provide a macro analysis of networks, termed by Jones *et al.* structural embeddedness and by Provan and Kenis (2008) network governance.

[44] Network governance scholars focus less on the structural features of the network. However, this does not mean that structural issues have been ignored. For instance, economic geography studies contribute to the understanding of regional industrial clusters by incorporating structural issues in their analysis (Boschma and Martin, 2010a).

[45] E.g., Uzzi (1997) investigates 23 New York apparel manufacturers and confirms Granovetter's argument that trust and long-term relationships are crucial for inter-firm interactions.

a weak tie as an indirect connection between two actors, which is based on a short-term and more opportunistic relationship.

Granovetter does not consider whether ties are created purposely or incidentally. He disregards the origins of networks and the forces that subsequently govern their growth and further articulation. This allows him to separate strong from weak ties without considering the relation between the strength of the tie in relation to its prospective purpose. In this thesis, networks are seen as purposive and, hence, the strength of the ties among network actors is relevant to their exploitation in prospective relationships. The strength of a tie does not necessarily determine its value. Ties play different roles, and the structure in which they are embedded is important (Storper, 1996).[46] For instance, weak ties can act as bridges between nodes (i.e., network actors) that are unknown to each other and may be important for spreading non-overlapping information across the network.[47] The assumption is that directly connected actors are likely to have access to similar if not identical information, because they share the same sources, but actors that are not directly connected may be more likely to bring new information into the network because they access different sources. Thus, the argument is that the larger the number of an actor's weak ties, the higher will be the chances of this actor accessing new (but not necessarily relevant) information. Bridges are important for the diffusion of information.

Similarly, the structural holes concept proposed by Burt (1992) contributes to the investigation of dyadic ties, the diffusion of information within networks and network efficiency. Burt (1992: 18) defines a structural hole as a relationship where there is non-redundancy between two contacts involved in a transaction. Redundant contacts lead the target node to the same people and spread information in a circular fashion with high probabilities of overlapping information.[48] The concept of structural holes developed by Burt contributes to the debate on the efficiency and effectiveness of networks, which is relevant for investigation and understanding of network structure and evolution discussed below.

---

[46] Grabher (1993) claims that the presence of strong ties in the Ruhr area in Germany trapped the region into negative lock-in, which was damaging to regional development.

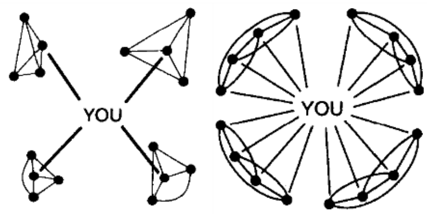
[47] All bridges are weak ties, but not all weak ties are necessarily bridges. For a comprehensive discussion on the features of bridges see Granovetter (1973: 1364).

[48] Burt, unlike Granovetter, considers that both strong and weak ties can be bridges.

The efficiency of a network stems from the likelihood that it is more advantageous (less costly) for a central node to have a few trusted direct links (which are costly to maintain) that are connected to other clusters of nodes (Figure 2.1a below), than to have direct ties with all the nodes in every cluster (Figure 2.1b below). If the direct links are based on trust, the central node is likely to have access to reliable information from various sources, which is an advantage (Burt, 1992: 20-21).

Figure 2.1 Network efficiency

(a) (b)



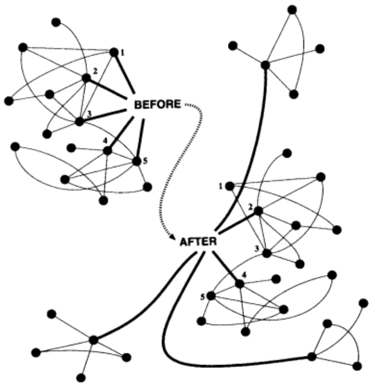
Source: Burt (1992: 17 and 20).

The effectiveness of a network is determined by the access to new information at network level. Since a given actor (the central node) has a fixed number of ties it is more effective to have direct ties to actors with connections to other networks ('after' position in Figure 2.2) than to have direct ties with actors in the same network(s) ('before' position in Figure 2.2). The higher possibility of connections with additional networks allows the central node greater access to non-redundant information. This is advantageous because:

> non-redundant contacts are only linked through the central player, you are assured of being the first to see new opportunities created by needs in one group that could be served by skills in another group. You become the person who first brings people together, which gives you the opportunity of coordinate their activities. These benefits are compounded by the fact that having a network that yields such benefits makes you even more attractive as a network contact to other people, thus easing your task of expanding the network to best serve your interests. (Burt, 1992: 23)[49]

[49] This quote indicates that, unlike Granovetter, Burt anticipates the formation of ties based on 'ulterior motives', and supports the above argument that networks are purposive and, hence, that the strength of ties among network actors is relevant to the purposes for which they might be exploited in prospective relationships.

Figure 2.2 Network effectiveness



Source: Burt (1992:22).

The investigation of dyadic ties provides empirical information at the individual level and, combined with evidence on the institutional arrangements in which ties are embedded, may contribute to our understanding of the structure of networks. This raises the question of whether there are optimal strong and weak ties (to use Granovetter’s terms) or structural holes (in Burt’s terms) combinations that would render networks more efficient and more effective. At one extreme, optimal combinations of strong and weak ties could be considered in the investment planning sense, which would cast network formation as a maximisation problem of the sort favoured by neoclassical economists. However, successful anticipation of optimal combinations is unlikely because: a) the costs of maintaining ties are difficult to predict, and b) the value of what would be gained is similarly uncertain. In the context of this thesis, firms are not isolated actors; they are embedded in dynamic settings which, when understood in combination with ties within networks, may provide evidence to support government action aimed at improving industrial development.

Provan and Kenis (2008) note that although networks have been extensively investigated, organisational studies of network governance pay scant attention to the governance of multi-organisational networks, perhaps because:

> organizational scholars are used to studying organizations, not multiorganizational arrangements [and] (…) there seems to be some reluctance among many who study networks to discuss formal mechanisms of control. A common assumption is that since networks are collaborative arrangements, governance, which implies hierarchy and control, is inappropriate. (Provan and Kenis, 2008: 230)

Also, organisational studies that address multi-organisational network governance and structure in general do not specifically consider the infancy and evolution of these networks, but rather refer to these aspects implicitly under the heading of network controlling mechanisms (Provan and Kenis, 2008). However, the study of network infancy and evolution is relevant for an examination of inter-organisational networks. The following elements may be conditions for the further development and articulation of the network: i) networks might be purposive or emergent with different consequences for their growth and articulation; ii) government efforts to promote networks may influence which type of network is more likely to emerge in a particular industry; iii) the level of openness of the network, often established at an early point in its history, influences its evolution; and iv) the existence in the network of a network broker may involve controlling mechanisms that deserve examination. An investigation of inter-organisational networks that addresses these issues could provide important insights for a more comprehensive understanding of networks and the proper role of policy to support network formation and maintenance.

Each of the four issues outlined above requires further examination. First, we find that purposive networks follow as the result of strategic actions implemented by government and that emergent networks follow as the result of spontaneous interactions among actors. The reasons why a network is formed may be significant for its governance. In purposive networks compared to emergent networks, ties may be more vulnerable to being broken, because the actors in purposive networks may have responded to a specific initiating event (such as a government incentive to engage in a network). However, over time, these motivations may be superseded by other incentives and developments and when put under pressure actors may reassess their ties and whether the initial reasons for engaging in the network remain valid. Emergent networks result from the creation of spontaneous ties based on an *ex-ante* assessment by the network actors that the costs of engaging in the network will be worthwhile in the short-term. Over time, these *ex-ante* expectations may or may not be fulfilled. However, the variety of motives and expectations related to emergent networks is likely to be greater and the ties will be less vulnerable to pressures from changing events.

The second issue, relating to the response of industry to the implementation of government policy, concerns the likelihood that firms will respond to government actions, which will depend on the following. Industry's response to government policy will be related to the dynamics in specific sectors. As already discussed, sectoral characteristics determine in part whether firms need to combine different sources of knowledge and engage with different types of actors; however, these needs may change over time. In addition, the power arrangement within a network (i.e. hierarchical or heterarchical) is likely to influence the network actors' responses to government intervention and power relationships are likely also to evolve over time, which will influence the controlling mechanisms within networks discussed further below.

The issue of the level of openness of regional networks is important for understanding network governance and how networks evolve over time. A proxy for the level of network openness is the number of actors in the network that are external to the region. This is an important measure because it is an indication of the level of risk that the region will become locked in 'functional', 'cognitive' and 'political' ways (Grabher, 1993).[50] The absence of inter-network ties in the regional network suggests that there is a higher risk of lock in occurring, as a result of what Grabher (1993) refers to as the 'weakness of strong ties', that is, the ties among network actors are so strong as to prevent changes that would allow the network to evolve in new and positive directions. When a network becomes dominated by one or more of the lock-in mechanisms described above, 'sclerosis' develops which jeopardises further network evolution. The level of openness of the network is a proxy for the absorptive capacity of the network actors (here we are concerned specifically with firms) and the regional network.[51] The ability of firms to access inter-network actors will be based on their level of absorptive capacity, and the inter-network ties they establish may prevent network lock in and indicate greater absorptive capacity.

The issue of controlling mechanisms within networks is important for understanding network governance. The empirical evidence on this issue is scant; most studies investigate dyadic ties and ignore the wider control mechanisms. Similarly, the foundational assumption that networks are collective arrangements precludes the

[50] 'Functional lock-in' occurs when the region is trapped into a rigid specialisation, 'cognitive lock-in' describes a situation of 'groupthink' that leads to regional development, and 'political lock-in' happens when there are symbiotic ties between the politico-administrative systems and industry representatives (Grabher, 1993).

[51] Absorptive capacity is the ability to de-codify and re-deploy knowledge developed externally (Cohen and Levinthal, 1990). Rousseva (2008) uses this proxy to investigate the absorptive capacity and technological capabilities of Bulgarian software firms.

observation of unbalanced power within network arrangements and represents a gap in organisation studies (Provan and Kenis, 2008: 230).[52] Although empirical evidence from social network analysis identifies network nodes that are more powerful, the focus is on analysing network representation (degree centrality), rather than investigating in depth the nature and motivations for tie creation or how these issues are linked to more or less powerful actors within the network. Institutional arrangements (rules and conventions) that are strongly related to the controlling mechanism are not captured by social network analysis (Cantner and Graf, 2010; Grasenick *et al.*, 2008). These studies do not capture institutional arrangements often because of data restrictions; if patents are employed as a proxy for innovation, it is possible to identify dyadic relationships (e.g. co-invention) which are not specific to the features or motivations determining tie creation. Also, the use of patents as a proxy for innovation excludes innovation activities that are not appropriated by patenting. Social network analysis combined with in depth investigation of network nodes and dyadic ties would explain how networks function and evolve, and suggest government interventions aimed at making networks more efficient and effective.

Investigation of the controlling mechanisms enables differentiation among brokered networks, shared-governance networks and mixed governance networks.[53] An examination of how controlling mechanisms are exercised within a network adds to our understanding of whether the network is dependent on one or a few particular actors and, therefore, the removal of these actors from the network may cause major disruption to its arrangement and result in its degeneration. Also, the identification of a heterarchical (shared-governance) or hierarchical (brokered) network arrangement may support the formulation and implementation of technology policy to create or support networks.[54]

In addition to network governance and structures with controlling mechanisms and dyadic ties, von Tunzelmann (2003) introduces the concept of network alignment, which is also relevant for understanding how networks evolve. Von Tunzelmann (2003: 46) takes a systemic approach and assumes that multiple networks are

---

[52] See the contribution by Cantner and Graf (2010).

[53] Brokers govern the network and can be internal or external to the networks; shared-governance networks occur when all the network participants govern the network collectively; mixed governance networks are where a single entity which is responsible for coordinating certain network issues and others are coordinated collectively.

[54] The use of social network analysis methods for visualising the representation of networks is useful in allowing a more accurate identification of the actors.

different elements ‘pulling in similar directions to one another, even when their purposes differ’. Network alignment refers to the consistency of heterogeneous networks and their ability to ‘orient their effectiveness towards attaining certain goals for the relevant systems’ (von Tunzelmann, 2010: 4). Von Tunzelmann’s contribution is especially useful for a consideration of whether the role of government in creating networks should include the issue of network alignment. This would mean that government support for the creation of networks may not by itself be a sufficient mechanism to foster knowledge exchange among the actors or to promote learning by firms; some level of alignment may also be required.

In the context of developing countries this could be important to challenge the view that the replication of support for networks is sufficient to foster firm innovation; in these contexts, the institutional setting required to achieve alignment is neglected. For instance, Pacheco and Corder (2009) note that, historically, Brazilian public organisations have been rigid, against change and, therefore, unlikely to be able to adapt to new demands. In their view, this problem has delayed the evolution of the country’s system of innovation. Dodgson *et al.* (2008) find evidence of a quite different phenomenon in Taiwan, where local institutions adapt to the needs of specific industries, which in part explains the country’s catch-up in the IT industry. In this case, network alignment was evidence at the national level (Kim and Von Tunzelmann, 1998).

This section has discussed the issue of network governance, which relates to the structure and functions of networks in which governance can be seen as a purposive or emergent feature. Although network governance has been differently defined by organisational scholars, all definitions are based on the premise that network actors are embedded in economic and social settings that influence their economic decisions and the formation of ties. Network coordination may benefit firms, particularly in development contexts, by helping to overcome information asymmetries. This thesis examines purposive networks, and hypothesises that the strength of ties among network actors may be advantageous for prospective relationships. Studies on the strength of dyadic ties may support an understanding of the structure and performance of networks, including their efficiency and effectiveness, especially if combined with evidence that relates to the institutional settings (and investigation of the infancy and evolution of networks) wherein dyadic ties are embedded. The evidence from such studies can be used to inform government actions to improve industrial development. Investigation of inter-organisational networks provides some clarification of the key elements that may influence the development and articulation of networks, providing important insights that should lead to a more comprehensive understanding of networks and the proper role of policy in supporting network formation and maintenance. This section demonstrates that the concept of network alignment may be relevant for an understanding of network evolution and the role of networks as sufficient mechanisms for knowledge exchange among actors, and learning-by-interacting among firms.

The next section discusses the systemic linkages within and among networks from the perspective of the firm.

2.4.2 Firm-level innovation and networks in developing countries

An understanding of firm-level innovation is relevant for firms' economic performance and development, since most economic activity is channelled through firms (Penrose, 1959: 9). Firms are the main recipients of the benefits from innovation and technological accumulation is localized mainly in firms (Bell and Pavitt, 1992; Malerba, 2004: 24). Innovation can be defined from different viewpoints. Some would claim that only radical inventions should be described as innovations and do not consider incremental innovation. The definition of innovation in the OECD (2005) Oslo Manual provides some resolution between these conflicting stances, and broadens the scope of investigation. It defines innovation as:

> the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations (…) The minimum requirement for an innovation is that the product, process, marketing method or organisational method must be new (or significantly improved) to the firm. (OECD, 2005: 46)

The Oslo Manual provides a comprehensive perspective on the measurement of innovation, especially in developing country economies where firm level innovations (i.e. practices or outputs new to the firm but not the market) are more frequent than market level (i.e. practices or outputs new to all the firms in the country) or international market level (i.e. practices or outputs new to the world) innovations (OECD, 2005: Annex 1).

Firm level innovations are often related to innovative firms' specialisation in knowledge production, and in the technologies employed, the products produced and the processes employed (Pavitt, 1998). This specialisation in knowledge production differs considerably between large and small firms (based on their different availability of the resources required to pursue innovation and operate under organisational arrangements),[55] and between sectors and industries (Freeman and Soete, 1997). Hence, a firm's innovation strategy will be influenced by firm size, sector and industry[56] as well as by issues related to technological, social and scientific path-rigidity (as discussed in Section 2.3.1). Innovation ability depends on experience at the micro level; over time, firms accumulate capabilities (Teece *et al.*, 1997), which influence their capacity to access and apply externally developed knowledge (Cohen and Levinthal, 1990) and to change or re-think their strategies. Firms' knowledge specialisation, knowledge creation, innovation strategies, dynamic capabilities, absorptive capacity and the systems in which they are embedded are determinants of the search for external and complementary knowledge, that is, through their network ties.

Bell and Pavitt (1992) stress the need to know more about the specific conditions favouring technological accumulation by firms in developing countries, which may involve participation in networks. The network concept assumes the presence of collective arrangements. It is useful for understanding innovation since it enables us 'to supersede the methodological individualism of Schumpeter's "heroic" entrepreneur' (DeBreson and Amese, 1991: 364). Both networks of innovators and collective actions are related to collective learning and the mutual benefits that each actor secures. They are a sub-set of systems of innovation (Cantner and Graf, 2010). A precondition for the existence of a network of innovators is synergy among agents, without which the network can fail. Cooperative relationships among agents are a

---

[55] E.g., Pavitt (1998) examines the case of knowledge specialisation in large firms, addressing the issues of internal control and coordination within the firm (i.e. governance) and linkages of interfaces within and outside the firm (i.e. network). He claims that these features are increasingly essential for the successful deployment by large firms of technological knowledge and for their commercial success. Small firms, on the other hand, can usually not afford investment in R&D on a similar scale to that found in large firms. The development of technological knowledge by small firms requires a different organisational structure. For a comprehensive study of micro and small firms see Rothwell and Zegveld (1982).

[56] Freeman and Soete (1997; Ch. 11) propose a range of innovation strategies including: offensive, defensive, imitative, dependent, traditional and opportunistic strategies. Each includes different combinations of in-house scientific and technical activities, which may provide useful insights for the empirical examination of firm-level innovations in specific industries.

'key linking mechanism in network configurations' (Freeman, 1991: 502). However, as already stated, it cannot be assumed that relationships are balanced, and hierarchical networks often emerge during network development.[57] Innovation in a developing country context often depends on whether and why firms engage with networks of innovators, in which types of networks they participate and how they are able to benefit from these arrangements. For instance, Bresnaham *et al.* (2001), used an industrial cluster approach and found that Ireland, Israel, India and Taiwan have benefited in different ways from engagement with leading US ICT networks to develop their own ICT industry; thus, they stress that contextual settings should be considered for policy making.

Research on innovation in developing countries aims, among other things, to explain how interactions among firms, and between firms and other organisations, support regions' or countries' economic development.[58] For example, Sagasti (2003) claims that networks are relevant for building strong endogenous scientific and technological systems in developing countries and that interactions among local actors, and with global counterparts are important for economic development.

Innovation studies do not always refer to these interactions using the language of networks; however, there is a level of consensus that technological and social capabilities require a long and gradual building process and that inter-organisation interactions may support the process of capabilities acquisition by firms and lead to economic development (Fagerberg and Srholec, 2008). We review some of these studies below.

Bell and Albu (1999) contribute to our understanding of how firms in developing countries can improve their capabilities through interactions. They consider the 'cluster' as their unit of analysis (clusters are defined as co-located and industry specialised groups of firms). They find that industry clusters in developing countries are comprised of firms with intra- and inter-cluster relationships, where inter-cluster

[57] E.g., value chain networks may use different kinds of governance related to the level of technological capabilities of suppliers and contractors. Value-chain suppliers may be more or less engaged with contractors' technological developments and, depending on their technological capabilities, may be able to benefit from knowledge spillovers (Pietrobelli and Rabellotti, 2009: 222-226). Developing country firms belonging to global value chains are usually involved in the lowest added-value activities (Chaminade and Vang, 2008).

[58] Another frequent issue in research on innovation in developing countries is the contribution of Foreign Direct Investment (FDI) to the development of indigenous technological capabilities (Costa and Queiroz, 2002).

relationships improve their ability to accumulate 'knowledge using' capabilities to build 'knowledge changing' capabilities.[59] Although the authors use an industrial cluster rather than a network approach, they stress the relevance of inter-organisation interactions for innovative firms involved in knowledge diffusion and open to external cooperation to acquire new knowledge (Bell and Albu, 1999: 1729). From a rather different perspective, but also using a cluster approach to address networks, Håkanson (2005) stresses the relevance of epistemic communities for the creation of trustworthy interactions, rather than the mostly found policy prescription of co-location of firms in specific regions aimed at the creation of collaborations.

Chaminade and Vang (2008) examine the role of inter-organisation interactions in capability building through an investigation of how regional systems of innovations in developing countries support firms in global value-chains in upgrading their activities. Their use of the value chain as a unit of analysis is another variant terminology to refer to a group of firms; in network terminology, value chains are purposive networks organised around a collection of goods or services produced by network participants and organised usually hierarchically among downstream (closer to final user) firms. According to Chaminade and Vang, firms that want to upgrade to higher added-value activities in the value-chain will be more successful if they are embedded in a region that supports interactive learning and innovation. This is because the development of higher added-value activities requires interactions among customers, firms and organisations (Chaminade and Vang, 2008: 1686). Chaminade and Vang claim also that regional systems of innovation in developing countries are often in an emergent stage and show the following features: i) interactions among systems components likely to be dominated by market transactions; ii) weak inter-sectoral ties; iii) absence of supporting organisations; iv) transfer of knowledge from universities, mainly through human resources training; and v) low level of interactive learning involving firms and other components in the system with competences related to new knowledge creation (Chaminade and Vang, 2008: 1689).

---

[59] According to Bell and Albu (1999: 1729), 'knowledge-using' capabilities involve maintenance of or expansion to production capacity or imitation of neighbouring firms' techniques while 'knowledge-changing' capabilities involve managerial skill in innovation, or 'the search for, selection, adaptation and assimilation of new product or process technology'.

Chaminade and Vang employ the ‘cluster’ approach (defined above). They argue that inter-organisation interactions are relevant for capability building, and that the development stages in the economic and institutional settings in which firms are embedded are crucial. They note also that systems of innovation in developing countries (in their analysis, regional systems) historically lack features that are important to support fruitful interactions between the components of the innovation system.

Viotti (2000) contributes indirectly to the examination of ‘lacking systemic features’ in developing countries, as discussed by Chaminade and Vang (2008). This is because Viotti questions the value of systems of innovation as an approach appropriate for explaining technical change in developing countries. His critique is based on the claim that the systems of innovation approach implicitly defines an innovation as something new, a breakthrough technology, and that developing countries are engaged in learning activities related to already existing techniques rather than of fundamental innovations. According to Viotti (2000: 4), learning:

> is the process of technical change achieved by *diffusion* (in the perspective of technology absorption) and *incremental innovation*. In other words, *learning* is the absorption of already existing techniques, i.e., the absorption of *innovations* produced elsewhere, and the generation of improvements in the vicinity of acquired techniques. By contrast, *innovation* is the process of technical change achieved by the production of (the first commercial transaction involving) a new product, process, system or organization. (emphasis in original)

He investigates the learning systems in Korea and Brazil and although his analysis is not aimed at the interactions in learning systems, he demonstrates that Korea’s efforts to construct an active learning system required active (as opposed to passive) interactions among local firms, and FDI companies in Korea. Despite some scepticism about the ‘systems’ approach, we find that inter-organisation interactions play a relevant role in capability building.

The lack of systemic interactions in developing countries’ systems of innovation is identified in empirical studies of innovation in Brazil (Cassiolato and Lastres, 1999, 2003), and has lead Brazilian scholars to develop an approach that is appropriate to investigate innovation in Brazil. This approach originally was described as the Local Productive Arrangement (LPA) approach, but has been renamed the Local Productive Arrangements and Innovation Systems (LPAIS) in order to include systemic as well as productive arrangements of firms (Lastres, 2007). The LPAIS approach uses empirical evidence gathered at the local and regional level in Brazil, to account for the presence of strong socio-economic and cultural differences. The approach has been applied to investigate innovation in Brazilian regions (for instance by Britto and Stallivieri, 2010; Campos *et al.*, 1998; Cassiolato *et al.*, 2008a; da Silva, 2008; Garcia and Souza, 1999; IPARDES, 2006; Machado, 2003; Teixeira, 2008).[60] Examples of successful cases of systemic interactions that could lead to technological and economic development are the exception rather the rule (as observed by Dantas, 2006).

Although the LPAIS approach deals with governance issues related to the presence of networks in clusters or industrial regions (particular investigating if there is a heterarchical or hierarchical type of decision making process, Redesist, 2005),[61] it does not examine the extensions to, features of or motivations for tie creation by firms within the investigated 'local arrangements'. Further research on the formation of regional networks of innovators in Brazil that investigates the creation of inter-organisational dyadic ties by firms is needed. The specific contribution of such research might be the examination of whether there is any consistency in these networks that explains the conditions under which networks will be effective for fostering and supporting firms' innovative activities, technological capability upgrading and industrial regional development.

Although, as the above examples illustrate, some studies of firm-level innovation and networks in developing countries follow a systemic approach, Fagerberg and Srholec (2008) note that the use of the systems of innovation approach in developing countries is relatively new,[62] as is the investigation of networks of innovators as a sub-set of the systems approach. Lundvall *et al.* (2009b) claim that investigations of developing countries systems do not comprehensively address two important issues: the relationships between organisations, often neglected in investigations of single

---

[60] E.g., a collection of studies edited by Cassiolato *et al.* (2008) provides empirical evidence of LPAIS and arrangements in eight Brazilian states.

[61] According to Redesist (2005: 3), 'in the specific cases of LPAIS governance refers to different coordination mechanisms among actors and activities involving the production and distributions of goods and services, as well as the processes of generation, employment and diffusion of knowledge and innovation. There are different modes of governance and hierarchies in productive systems, which represent different power mechanisms in decision making processes (centralised and decentralised; more or less formalised)'. (my translation)

[62] Cassiolate and Lastres (1999) and Cassiolato *et al.* (2003) provide extensive evidence on Mercosur (i.e. Brazil, Argentina, Uruguay and Paraguay).

organisations;[63] and the need for indicators 'that reflect the quality of relationships such as trust' (Lundvall *et al.*, 2009b: 19).[64] Lundvall *et al.* consider that empirical investigations would be more useful if they used methods that grouped systems into 'families' based on commonalities, which would increase comparability. With regard to comparisons between regional systems in developing countries, Padilla-Pérez *et al.* (2009) claim that research on regional systems of innovation in developing countries tends to be generic and does not provide sufficient evidence that is specific to the firms located in these systems or information on the specific stage of evolution of the system. The authors call for more systematic comparison among regions (Padilla-Pérez *et al.*, 2009: 141).

It has been argued that interactions among the components of developing country systems are often weak, dysfunctional or misaligned, and it is plausible that innovation networks, which are a part of the larger system of innovation, will show similar patterns. However, there is no systematic empirical evidence to test this conjecture,[65] which demonstrates the need for more detailed investigation of regional networks of innovators in developing countries. An investigation of regional networks would provide evidence related to regional systems as discussed by Padilla-Pérez *et al.* (2009).

There is some evidence from studies of networks in developing countries on the existence of systemic links in developing country regions. Recall the case of Taiwan's IT industry which shows that networks are relevant for firms' capability upgrading, and that systemic linkages were present and partly explain IT industry development in Taiwan. Giuliani (2010) investigates business and knowledge networks in the Chilean and Italian wine industries and finds that knowledge related (but not business related) ties among firms are positively correlated to firm performances. Giuliani's findings show that different types of links (in her study business and knowledge links) are not necessarily homogeneous within a region. She notes also the need to investigate further the type of (firm-level) conditions required to foster the formation of links that positively affect firm performances.

[63] As discussed above, organisational studies tend to favour investigation of intra-organisational interactions over inter-organisational interactions.

[64] The issue of trust is addressed in Fagerberg and Srholec (2008) which examines social capital across countries, claiming that it is an important aspect that needs to be considered in an examination of innovation in developing countries.

[65] For example, Cimoli (2002) discussed the role of networks within innovations systems in Latin America from the conceptual perspective.

Dantas and Bell (2009) contributed to the debate on networks in developing countries by examining the knowledge network of the state-owned Brazilian firm, Petrobrás, and showed that its knowledge network has become more complex over time and is positively correlated to the firm's capabilities for technological upgrading. Although their empirical evidence does not provide information on the broader inter-organisational interactions, it is consistent with claims that the building of systemic links is a long term and gradual process and is relevant to technological development.

2.5 Summary

This chapter discussed the role of networks in the economy, claiming that they are at the core of systems of innovations, are related to technological and institutional dynamic paths, and show different structures across regions and industries. Particular attention was paid to networks of innovators, in which firms are core actors. A better understanding of how networks of innovators emerge and evolve, through an examination of their structure defined by the existence and nature of dyadic ties among actors, may enable a better explanation of whether and why innovative firms participate in networks.

It has been argued that networks of innovators in developed economies can forge systemic linkages that position their economies at the technological frontier of global knowledge specialisation. Some works, such as Pérez (2008) and von Tunzelmann and Acha (2006), conclude that networks combine new types of complementary knowledge which may play a crucial role in industrial development and technological catch-up. A few examples of successful networks of innovators in developing countries, such as the cases of Japan and Taiwan, suggest that such an approach might be relevant for technological catching-up.

The literature review highlights the lack of empirical evidence on networks of innovators in developing countries. More work is needed on what drives innovating firms in developing countries to create dyadic ties and engage in networks. There is a lack of evidence on the roles played by networks in developing country systems of innovation, and especially on how the governance of networks is related to firm level innovation performance.

We argued that studies of multi-organisational network governance and structure tend to ignore the infancy and evolution of networks, both of which are relevant for an examination of inter-organisational networks because of the following elements: i) networks might be purposive or emergent; ii) government efforts to promote networks may influence which type of network is more likely to emerge in a particular industry; iii) the openness level of the network influences its evolution; and iv) the existence of a network broker within the network may involve controlling mechanisms which deserve examination. Hence, investigation of inter-organisational networks that addresses these issues would provide important insights for a more comprehensive understanding of networks of innovators.

The examination of purposive networks of innovators, that is, networks formed as a result of technology policies and government intervention, may be explanatory variables for understanding whether and how regions locked into negative path rigidity can change direction through endogenous or exogenous processes.

We showed also that the adoption of the systems of innovation approach to developing countries is relatively new (Fagerberg and Srholec, 2008), as is investigation of the networks of innovators as a sub-set of systems. Investigation of developing country systems should focus on two issues: i) the relationships among organisations as opposed to investigation of single organisations; and ii) indicators 'that reflect the quality of relationships such as trust' (Lundvall *et al.*, 2009b: 19). Empirical investigations in developing country contexts would be more useful if they employed methods that grouped systems into 'families' based on their commonalities, thus providing a basis for comparability. Studies comparing regional systems in developing countries provide little evidence on the specificities of firms located in these systems or the specific stage of evolution of the system. There is also a methodological need for systematic comparisons among regions (Padilla-Pérez *et al.*, 2009).

Finally, this chapter demonstrates that studies on Brazilian regional experience related to innovation and governance have been influenced by the LPAIS approach, which relates governance to hierarchical or participatory decision making processes within regions (Lastres, 2007; Redesist, 2005). Although studies using the LPAIS approach cover a wide array of Brazilian regions, they do not consistently investigate the extension to, nature of and motivation for tie creation among firms in Brazilian arrangements or systems. Further research is needed on the formation of regional networks of innovators in Brazil, and particularly the creation of inter-organisational dyadic ties by firms and whether there is consistency in these networks. This would highlight the role of networks to foster and support Brazilian firms' innovative activities, technological capability upgrading and industrial regional development.

A more comprehensive understanding of the above issues is crucial if government intervention in developing countries is to result in technological development and economic catch-up, especially when policy is related to the formation of networks.

Chapter 3 investigates the formation of the Brazilian software industry, which followed the implementation of a government programme. It provides the context for the research questions formulated in Chapter 1.

CHAPTER 3 – THE BRAZILIAN SYSTEM OF INNOVATION AND THE LOCAL SOFTWARE INDUSTRY

3.1 Introduction

This chapter examines the emergence and development of the Brazilian software industry, in particular, the motives and mechanisms that supported the creation of regional networks within the country to foster the local software industry. Following the system of innovation approach discussed in Chapter 2, we argue that the emergence and development of the local software industry was contextualised in the country's industrial development and the institutional set up created to support a network oriented approach to development. The Brazilian industrialisation process was influenced not only by the internal economic context, but also by the institutional set up in which firms were embedded. Section 3.2 provides an overview of the Brazilian industrialisation process, highlighting the creation of organisations by the government to support industry development generally and network formation in particular. Section 3.3 examines the software industry, following a sectoral systems of innovation approach, aimed at contextualising the emergence and development of the Brazilian software industry. Section 3.4 concludes the chapter.

3.2 Industrial development in Brazil - towards a system of innovation: an overview

This section introduces the mechanisms of industrial development in Brazil, focusing mainly on the creation by national government of relevant organisations to support local science and technology (S&T) activities and to foster technological progress and economic development.[66] Section 3.2.1 discusses the history of the organisations related to S&T activities. Section 3.2.2 examines the period when national government took an active role in supporting industrialisation and the creation of S&T organisations. Section 3.2.3 examines the country's more recent industrial development, again highlighting the creation and restructuring of S&T organisations. Section 3.2.4 summarises the section.

---

[66] It is important to highlight that this section is not intended to cover all the initiatives related to industry and technology policies in Brazil throughout the country's industrialisation process; such a task is beyond the scope of this thesis.

3.2.1 From the early days to the mid-1960s

The Brazilian system of innovation, as we currently understand the concept (Edquist, 2004; Freeman, 1987; Nelson, 1993), dates from the 1950s when national government deliberately created S&T organisations to support economic development. At that time, it was common practice among catching up countries to adopt developed economy initiatives to support economic development and growth, which included the creation of S&T organisations to support technological progress (Pacheco and Corder, 2009).

However, before the 1950s the Brazilian national government had created some S&T related organisations, although not deliberately following the argument that technical progress was crucial for economic development. Some of these organisations date back to the 19th century (created under the regime of monarchy) and were created to build local knowledge in specific areas related to the country's main economic activities at the time, such as mining, public health, and coffee growing.[67]

World War I made it difficult to import goods and triggered further industrialisation via import substitution (Tavares, 1972; Versiani and Versiani, 1977).[68] Local production of many goods did not require local sophisticated research capabilities or engineering manpower; purchasing and sometimes copying technology developed abroad were common practice (Dahlman and Frischtak, 1993: 417; Suzigan, 2000). By the 1930s, industrial development was underway in Brazil, although in the form of more meagre and less competitive industries compared to the developed economies (Suzigan, 2000).

Local industrialisation became critical for the country's economic growth during World War II when the import of key inputs (steel and capital goods) became almost impossible (Dahlman and Frischtak, 1993: 417). The resulting shortages led to the national government investing in industries that could provide independence (although partial) in certain inputs. Hence, by the early 1940s the national

---

[67] According to Dahlman and Frischtak (1993: 416) the move of the Portuguese Royal family to Brazil triggered the creation of S&T organisations such as the Medical School of Bahia, the Medical School of Rio de Janeiro, the National Library, the Royal Farm, and the National Museum. Along the same lines, Pacheco and Corder (2009: 10) point to the creation of: the National Observatory (1827), Ouro Preto Mining School (1876), Agronomic Institute (1887), the São Paulo Institute of Technological Research (1899), and the Oswaldo Cruz Foundation (1900).

[68] E.g., Versiani and Versiani (1977) provide a discussion of the effects of the variation in international exchange rates for investment in the Brazilian textile industry, the most important industrial sector in the early stages of the Brazil's industrialisation.

government was investing in capital intensive industries, such as steel and pulp and paper. Brazil entered World War II in 1942, which promoted the creation of university funding for research in national defence related industries (Pacheco and Corder, 2009: 11). By the end of the World War II, national government had extended its investment to heavy engineering, iron ore and chemicals (alkali). National government also created the Technology Department in the Ministry of Aeronautics. This Ministry supported the later creation of the Technology Centre in Aeronautics-CTA, and the Aeronautics Technology Institute-ITA, two crucial organisations that supported the development of a local aircraft industry in subsequent decades (Oliveira, 2004). From the late 1940s to the mid-1950s government invested in heavy chemicals, heavy mechanical and electrical machinery, railway equipment, motor vehicles and shipbuilding (Suzigan and Villella, 1997).

After the 1950s, Brazil's industrialisation process intensified and government implemented deliberate S&T policies to support economic growth through the creation of S&T organisations. These policies were in tune with the view of national government that the country had to catch-up with other developed countries (such as USA, the UK, Canada and France) in the development of nuclear energy, considered a crucial pre-requisite for national security at the time (Morel, 1979: 45). In line with this mission, national government aimed to support the training of the local labour force, as well as coordination and support for local scientific knowledge development. The latter occurred through the creation of the National Council for Scientific and Technological Development (CNPq) and the former was supported by the creation of the Agency for the Support and Evaluation of Graduate Education (CAPES), both in 1951. CAPES and CNPq were part of a strategy aimed at the results from national security investments spilling over to other economic sectors which were expected to support national economic growth. Economic development depended on two essential institutional systems: the network of local universities (undergraduate and postgraduate degrees) and public research organisations (Morel, 1979: 52). Within this strategy, national government created S&T related organisations, such as: i) the R&D Institute (IPD) in 1953, to study and solve social and technical problems related to the airspace industry; ii) the National Council in Nuclear Energy (CNEN) created in 1956, to develop applied research in nuclear energy, and iii) the National Institute of Metrology (INPM, now INMETRO) to support industry product standardisation (Pacheco and Corder, 2009).[69]

Industry policies were implemented to create organisations devoted specifically to industrial development, including the Brazilian Development Bank (BNDE, in 2011 BNDES) in 1952.[70]

In 1956, national government implemented a programme to foster and support economic growth and development, explicitly choosing industrialisation via import substitution (IIS) as an economic development model for catching-up with developed economies. This was a common trend in Latin American countries (Pérez, 2001). The Brazilian IIS model was very specific with regard to the roles attributed to the private and public sectors and multinational corporations (MNCs).[71] According to the Brazilian government, it was necessary to achieve high levels of industrialisation in the short-term and MNCs offered mature technologies that were less risky for investment; hence, MNCs benefited from special regulations for the import of capital goods (Pacheco and Corder, 2009; Ritz, 2008).[72] Government argued also that the national industry was not sufficiently technologically developed to provide the quality or quantity of the products offered by MNCs. This suited MNCs, which were seeking new markets for investment due to market saturation in the developed economies (Pérez, 2008), hence their interest in investing in Brazilian subsidiaries.

However, MNCs incorporated technology and knowledge developed in their parent firms and performed only low level R&D activities in Brazil.[73] These firms updated and adapted products developed abroad to local market needs, which represented weak modernisation for Brazil. The goods produced locally by MNCs were lower quality than those produced in their home countries. In addition, it was argued that

[69] Although national government created the infrastructure for the local development of S&T activities, according to Bielschowsky (1978) this infrastructure was not effective at decreasing Brazil's current technological dependence. According to him, this was because of lack of coordination between the S&T and economic policies.

[70] The role of BNDES in supporting local industry and the country's infra-structure has changed throughout its history. For a detailed discussion on which public organisations were created by national government to support industrial policy, see Suzigan (1978).

[71] These roles were part of industrialisation triad ('Tripé da Industrialização').

[72] Pérez (2001) claims that technological catching-up based on mature technologies is unlikely to occur because they show decreasing profits and productivity at this stage in the product life cycle, which partly explained the failure of Latin American countries to catch up with developed economies. See Pérez (2001) for an extensive discussion on this issue.

[73] This corroborates the argument that firms give preference to their original scientific systems for performing R&D activities, put forward by systems of innovations studies (see Chapter 2).

MNCs did not support significant levels of knowledge and technology transfer into the local innovation system in most Latin American countries (Cimoli, 2002).

To support the role of MNCs in the Brazilian industrialisation processes, government provided fiscal and financial incentives to attract and assure their investments. MNCs were mostly involved in the production of capital intensive and durable consumer goods, they had the knowledge and financial requirements necessaries for the installation of these types of industries. Brazilian firms were neither financially nor technological competitive compared to the MNCs, and were involved mainly in investments in non-durable and intermediate consumer goods (Tigre *et al.*, 2002). Alongside industrialisation via import substitution, government implemented policies to protect the internal market against imports and, therefore, international competition.

Moreover, the Brazilian government became increasingly more involved in economic development. This occurred basically through two mechanisms: i) high investment in key inputs and infra-structure, such as energy, transport, automobiles, and petroleum refining; and ii) the implementation of regulations that initially supported machinery import by multinationals in more intensive technology sectors (the local capital goods industry was not fully developed) (Pacheco and Corder, 2009).

Hence, in the 1950s there was a continuity of the investments that had started in the 1930s, demonstrating the active and developmental role of national government, aimed at assuring economic growth and development based on coordinated action. At that time, there was a clear understanding in the developed economies that technical progress was crucial for economic development and also that market mechanisms would not assure the necessary investment in S&T activities, which called for strong state intervention to guarantee positive outcomes from economic investment. The Brazilian government followed this international trend.

3.2.2 Mid-1960s to early 1990s

At the beginning of the 1960s the Brazilian economy faced an economic downturn and high inflation rates, followed by political instability, which contributed to the 20 years of Military Dictatorship that began in 1964 (Dahlman and Frischtak, 1993). The military governments continued high investment in the institutional set up to support S&T activities. The BNDE Fund for Techno-scientific Development (FUNTEC) was created in 1964 to provide human resources training through technical post-graduate programmes in local universities, following the argument that the shortage in science and human resources (especially those related to the productive sector) represented a bottleneck to the country's economic growth (Morel, 1979). In the same year, BNDE created the Fund for Acquisition of Machinery and Industrial Equipment (FINAME), to develop the capital goods industry. The Brazilian Innovation Agency (FINEP) was created in 1965 to manage state funding of special projects and programmes, and later FUNTEC funds. According to Pacheco and Corder (2009: 18), FINEP was the embryo of a system for financing Brazil's technological development.

In the early 1970s, national government implemented the first National Development Plan (PND) aimed at economic and social development, which was related explicitly to S&T activities. In this period there was an important shift towards the creation of public organisations and public support for industries that later would foster the development of the Brazilian software industry; for example, the Research Centre for Telecommunications (CPqD) in 1974, which was part of Telebrás, the Brazilian state-owned telecommunications firm, and the Renato Archer Information Technology Centre (CTI/CenPRA) in 1982, a public organisation devoted to R&D in information technology. Other important public organisation were created, including: i) the National Institute for Intellectual Property Rights (INPI) created in 1970 to assure the transfer of technologies created in the country; ii) the National Institute for Space Research (INPE) in 1971; iii) the Brazilian Centre for Management Support to Micro and Small Firms (in 2011 SEBRAE) in 1972; and iv) the Brazilian Agricultural Research Corporation (EMBRAPA) in 1973 (Pacheco and Corder, 2009).[74] Dahlman and Frischtak (1993: 419) summarise the state's role during the military period as follows:

> Overall, the military period can be characterized as a time when a planning system was established for S&T and strong emphasis placed on institutional development. Science and technology were perceived as important elements for enhancing national power. (…) these tendencies found expression in a strong emphasis on strengthening national technological capability in military and strategic areas such as informatics, telecommunications, the defence industry, aviation, and nuclear energy.

[74] Table A1 in the appendix presents a summary of the main organisations created to support the development of the Brazilian innovation system during this period.

Military governments financed economic development using internal and external debts mechanisms. The latter created a high level of vulnerability in the Brazilian economy to international economic downturns, such as those resulting from the international oil crisis in the 1970s. These downturns led to decreased Brazilian exports and a decline in the internal rate of economic growth resulting from over capacity in installed production (compared to real internal market demand). Local macro-economic instability and high inflation rates, influenced the low rates of economic growth throughout the 1980s, which has been described as a 'lost decade' in terms of economic development (Carneiro, 2002). The internal market declined and private and public investment was low compared to previous decades. Several economic plans were implemented during the second half of the 1980s to control this macroeconomic instability and high inflation.[75] These plans were successful only in the short term and did not resolve the country's economic instability.

During the 1980s, an important institutional change was the creation of the Ministry of S&T (MCT) in 1985, which aimed to coordinate the national S&T system. The S&T organisations created under previous governments, including CNPq, came under MCT (Pacheco and Corder, 2009).

At the end of this period, Brazilian firms were characterised by poor competitiveness and low technological development compared to MNCs and most products developed by local private firms were adapted from foreign technology absorbed via the mechanisms of import substitution; technology transfer from multinationals to local firms was rarely at the knowledge frontier in many industries. The R&D activities of local private firms were low-level compared to the leading economies. For instance, in 1990-1992 Brazil's expenditure on S&T represented 1.23% of its GDP and 75.5% of this expenditure was by the Brazilian government; whereas developed countries' expenditure on S&T activities represented 3% of their GDP, of which 40%-60% was private sector investment (Velho and Saenz, 2002). In addition, local R&D activities related more to (incremental) improvements than to radical innovation (Tigre *et al.*, 2002). The liberalization process started in Brazil at the end of the 1980s and was strongly associated with the failure of internal market

[75] Such as 'Plano Cruzado', 'Plano Cruzado II', 'Plano Bresser', 'Política do Feijão com Arroz', and 'Plano Verão'.

protection and a model of industrialisation via import substitution for economic growth. Section 3.2.3 addresses this issue.

3.2.3 Early 1990s to late 2000s

A new government came to power in Brazil in the early 1990s; the first democratically elected president since the end of the military dictatorship in 1985, assumed control of the national government. This represented a major shift in the role of the Brazilian state and had implications for how the institutional settings supporting local S&T activities evolved in that decade. The new government assessed the IIS model adopted mainly from the mid 1950s and concluded that its positive outcomes had been exhausted. It claimed also that the IIS model created a protected internal market with low internal and external competitiveness, which was hampering national industrial modernisation. The new government implemented a liberalisation of the Brazilian economy following the arguments that:

> economic liberalization reduces static inefficiencies arising from resource misallocation and waste; (ii) economic liberalization enhances learning, technological change, and economic growth; (iii) outward-oriented economies are better able to cope with adverse external shocks; (iv) market-based economic systems are less prone to wasteful rent-seeking activities. (Rodrik, 1993: 7)

The new government argued that the shift from the old internal market protection to free competition market mechanisms would trigger a restructuring of the local industry, would push local firms to up-date their products (Baumann, 2000; Markwald, 2001; Tigre, 1993; Tigre *et al.*, 2002). In later years, the non-tariff barriers related to import quantity restrictions (firms were allowed to increase the number of products in their imports portfolio) were eliminated, and temporary laws were introduced that suspended or eliminated most of the fiscal incentives and government subsidies (Carneiro, 2002: Chapter 10). Government claimed that local firms, facing international competition in the internal market, should make modernisation efforts to produce better and cheaper products compared to those produced under the internal market protection mechanism (Arbix, 1997).

It is argued by some, such as Evans (1995) and Chang and Rowthorn (1995), that the main consequence of the implementation of liberal government policies, such as occurred in Brazil, is an increasing absence of the state as coordinator, and erasure of its institutional builder characteristic, which according to these authors is essential for driving economic agents to take concerted action. The liberalisation process continued throughout the 1990s and, as a consequence, the internal market was exposed to more vigorous foreign competition. According to some authors, for instance, Pacheco and Corder (2009: 24), and Lastres (2007), the consequences for national industrial development were: i) depreciation in the country's industrial infra-structure; ii) reduced employment; iii) outsourcing and higher imports of inputs and components; iv) more attention to organisational innovation; v) lower industrial investment; and vi) take over by multinational firms of sectors once supported by government investment, for example the telecommunications industry (the results of the privatization of telecommunications partly explain the initial development of Brazil's software industry, see Section 3.3.2).

Villaschi (1993) claimed that the liberalisation process would weaken the Brazilian national system of innovation, for example, public investment in S&T, and reinforce the institutional constraints identified in the 1980s. His claims are confirmed by studies that analysed the liberalisation process in different industries.[76] For example, Tigre *et al.*, (2002: 7) show that from 1993 to 1996 there was a significant increase the country's expenditure on trademarks, patents supply of industrial technical cooperation and supply of industrial technology, with no proportional increase in private R&D expenditure. However, liberalisation spurred the modernisation of some industries that benefited from imports of equipment, such as ceramics and steel. In the case of ceramics, local producers had access to improved materials and technologies (Tigre *et al.*, 2002).[77] This leads to the conclusion that deregulation of technology imports had a partially negative effect on local technological efforts, since the capital goods and technology-based durable industries were the most affected (Tigre *et al.*, 2002).[78] Also, university-industry links in Brazil became less intense (Dagnino and Velho, 1998).

[76] E.g., the following studies discuss the negative effects of the liberalisation process for Brazil's technological development: Tigre and Junqueira (1999) for the IT sector, Mani (2001) for several industries, Velho and Saenz (2002) more generally, Tigre *et al.* (2002) for the automobile, and telecommunications industries, Szapiro *et al.* (2002) for the telecommunications sector, and Salerno *et al.* (2002) for the automobile industry.

[77] The Brazilian aeronautics industry is another example of a local industry that benefited from liberalisation of the Brazilian economy. Its modernisation resulted in increased exports from this industry throughout the 2000s (Bonelli and Pinheiro, 2007).

[78] A classic example is the Brazilian auto-parts industry (Costa, 1998).

In 1992, in the context of a liberalised economy, national political turmoil, high levels of macro-economic instability, inflation and public debt, a new national government came into power.[79] The new government inherited a partial de-structuring of the public institutional arrangements built by the Brazilian state since the 1950s. However, sorting out the macro-economic instability (i.e. high inflation and low economic growth) had to be prioritised over issues of discontinuity in the implementation of S&T related government programmes. Government concluded that once the macro-economic instability was solved, new political reforms aiming at a new institutional arrangement could be put in place to support economic development (Pacheco and Corder, 2009).

Macro-economic stability was achieved in the mid-1990s, which, combined with liberalisation of the Brazilian economy, resulted in a steep increase in imports and low growth in exports in the second half of the 1990s. After 1999, the level of imports reduced considerably as a result of devaluation of the Brazilian currency – the Real; this created expectations about increased Brazilian exports, which were disappointed due to low levels of growth in other economies and the crises related to provision of energy in Brazil. Exports began to increase again from 2002 and even more so in 2004 since when the Brazilian economy has shown considerable growth (Castilho and Luporini, 2010: 10).[80] Regarding the technological content of Brazilian exports, Castilho and Luporini (2010) find that low added value traded products, often related to commodities (e.g. minerals, oil, coal) increased considerably during the first decade of the 2000s. At the same time, there were significant increases in exports from specific industrial sectors, such as machinery, tractors and transport equipment (this refers especially, but not only, to trading with neighbouring countries in Latin America). Castilho and Luporini (2010) finds that the relative increase in the value of exports in commodities over the exports in industrialised products is associated with the increase in the international price of commodities and, hence, claim that there was no shift in Brazilian export trade towards low added

[79] The president elected in 1990, who was responsible for the higher liberalization process, was impeached at the end of 1992 and a new government was established.
[80] Brazil GDP in 2003 was 1.1% , 5.7% in 2004, 3.2% in 2005, 4% in 2006, 5.7% in 2007 and 5.1% in 2008 (IBGE, 2009).

value products (often associated with commodities) in the first ten years of 2000s (Castilho and Luporini, 2010: 20).[81]

The substantial economic growth experienced during the 2000s was corresponded with public investments in S&T, some of the following indicators show the results of these investments: i) the combined investment in scholarships by CAPES and CNPq increased from R$813M in 2001 to R$2.635M in 2010 (MCT, 2011); ii) the combined number of scholarships offered by CAPES and CNPq increased specially from 98.684 in 2007 to 149.579 in 2009 (MCT, 2011); iii) the total number of graduated masters and PhDs increased from about 26 thousand in 2001 to 50.2 thousand in 2009 (MCT, 2011); and iv) the number of scientific articles published in indexed journal from the Institute for Scientific Information basis increased from about 12 thousand in 2001 to 32 thousand in 2009 (MCT, 2011). The new S&T institutional framework implemented during the 2000 decade contributed to these performances. Section 3.2.3.1 discusses the new S&T institutional framework created in Brazil from the late 1990s throughout the 2000 decade.

3.2.3.1 The New S&T Institutional Framework in the 2000s

The discussion above showed that by the late 1990s the Brazilian S&T systems experienced the following: i) disarticulation between the scientific knowledge produced in the country and demand from the productive sector (as discussed by Villaschi, 1993); ii) the private sector was still showing low R&D investments compared to the developed economies;[82] iii) the old financing mechanisms to support S&T activities were ineffective and new mechanisms had to be created; iv) the S&T system largely lacked solutions to the major socio-economic problems, such as poverty, education, violence, unemployment and regional differences (Pacheco, 2007; Pacheco and Corder, 2009). At the end of the 1990s, national government implemented a new policy to restructure the financing of S&T activities, and aimed at guaranteed long-term financing, which was different from past policies that had been implemented in a context of economic instability (Pacheco, 2007).[83]

---

[81] See Castilho and Luporini (2010) for a detailed discussion on the Brazilian trade balance in 2000-2010.

[82] For instance, at the beginning of the 2000 decade, Brazil's expenditure in R&D was of 1.4% of its GDP, and 36.7% invested by the private sector (Pacheco, 2007: Table 1).

[83] Lastres (2007) also discussed the short termism of government policies due to macro economic instability, which according to her was an implicit policy influencing the country's performance on S&T activities.

In 1999 national government created Sectoral Funds to support R&D activities in specific sectors, to be administered mostly through the National Fund for Scientific and Technologic Development (FNDCT/FINEP).[84] The arrangement of Sectoral Funds involved: 13 funds created between 1997 and 2001, of which 2 had a horizontal approach and financed more than one sector – the infra-structural and university-industry links Sectoral Funds, the other 11 were vertical funding for petroleum, energy, transport, hydro-resources, aerospace related activities, telecommunications, biotechnology, agribusiness, health, aeronautics and information technology (including the software and other industries). The sources of funding for each Sectoral Fund differed and was a percentage of the income generated by each sector (Pacheco, 2007: 13).[85]

Government also implemented an initiative that aimed to solve institutional dysfunctions in the Brazilian system of innovation through the approval of a new legislation that allowed the creation of social organisations, which are non-profit organisations that act on behalf of public interest (associations, foundations, civil society organisations). This initiative followed government assessments that there were excessive levels of bureaucracy in the public administration, which led to inefficiencies in government programme implementation and also discontinuity of funding (Pacheco and Corder, 2009). Social organisations operate under management contracts, which allow them to request and manage public funding to invest in human resources, equipment and facilities on behalf of public authorities. They are also allowed to receive funding from other sources than government.[86] For instance, some organisations, originally under the supervision of the MCT administration, became Social Organisations, with the aim of improving the administration of public funding.

The creation of the Center for Strategic Studies and Management in Science, Technology and Innovation (CGEE) in 2001, under the Social Organisation arrangement, aimed to support the frail networking between universities, research

---

[84] With the exception of the fund for telecommunications - FUNTELL, this was managed by the Ministry of Telecommunications.

[85] Originally allocation of the Sectoral Funds was negotiated by committees with representation from: the MCT and its agencies, sectoral ministries, regulation agencies, scientific communities and the private sector. According to Pacheco and Corder (2009), arrangements changed in 2004 when the new national government came into power and the decision process became less democratic and more centralised in government.

[86] http://pgpe.planejamento.gov.br/os.htm, accessed 15 August 2010.

centres and the private sector. The CGEE was originally the Technical Secretariat for the Sectoral Funds but this role was taken over in 2003 by the MCT.[87]

In the early 2000s, national government formulated the Programme to Support Innovation in Local Productive Arrangements, which followed an approach developed by Brazilian academics to investigate industries geographically confined in Brazil, the LPA approach (discussed in Chapter 2, Section 2.4.2). The programme was financed by the university-industry links horizontal sectoral fund (the 'Green and Yellow Fund') and CNPq scholarships (Lastres, 2007). This programme was implemented in the 2000s (Teixeira, 2008) and its administration shifted among different government representatives over this period.

Lastres (2007: 13-15) assesses the LPA programme implemented during the 2000s and does not refer explicitly to the programme's aims as technology policy oriented. However, her discussion points to elements of technology policy in the programme, namely that the aims: i) contribute to the cooperation among agents within the 'arrangement'; ii) foster, at the global level, partnerships between firms, and among firms and government bodies, R&D organisations, and universities; iii) support actions to foster higher levels of synergy among the actors within the 'arrangement', possibly leading to a systemic production chain; iv) support actions to improve the coordination and management of LPA; and finally, v) support actions aimed at personnel training and technological capabilities in the relevant industries. The LPA programme followed different stages. The first identified arrangements within the country, following regional and local, public and private sector efforts aimed at: i) solving or minimizing the effects of economic liberalisation; and ii) coordinating the agents involved in the productive process to increase innovation and industrial competitiveness.[88] In a second stage local arrangements were selected for financial support. In both stages priority was given to coordination among local agents, in the first identification stage to measure the level of coordination and in the second stage to improve coordination. This highlights the relevance of governance within these 'arrangements'.

---

[87] The Sectoral Funds are under the control of the Brazilian MCT. CGEE is a think tank that manages public funding to produce technical studies and workshops that support the discussion of national strategy for the country's S&T development.

[88] Some examples of the regional industries targeted by local initiatives are: household ceramics, aerospace, IT and furniture industries in the São Paulo State, and the leather shoes in the Rio Grande do Sul State. For a more comprehensive study see Cassiolato and Lastres (1999) and Cassiolato *et al.* (2008).

Lastres, in the same report, discusses some of the limitations to programme implementation. She claims that there was conflict between policies aimed at local development and social inclusion, and those to promote innovation. This is explained in part by agents in some local arrangements perceiving new knowledge as knowledge incorporated in new machinery, and innovation as being related only to process improvements. Therefore, the strong cultural characteristics of these ‘local arrangements’ contributed to the neglect of important issues related to development. These findings reinforce the argument that although regions differ, they have social and cultural commonalities that need to be addressed (see discussion in Chapter 2, Section 2.2.1). This is relevant to the study of regional systems of innovations, or ‘arrangements’ (in Lastres’s terminology), proposed by Asheim and Gertler (2004), who claimed that although regions differ, they are circumscribed within a national context that cannot be ignored in the examination of regions.[89]

At the end of 2003, the new national government approved and implemented the Industrial, Technological and Foreign Trade Policy (PITCE), which prioritised four industries for public investment: capital goods, software, semiconductors, and pharmaceuticals. According to Pacheco and Corder (2009), PITCE’s results were disappointing compared to its original aims, but are important to highlight the relevance of industrial policy in the new government’s agenda. Among the reasons for these poor results it is argued that issues related to network governance and misalignment are central (Pacheco and Corder, (2009: 34):

> [PITCE’s] difficulties related to the macroeconomic context include lack of articulation between the government instruments and firms’ demands, the precarious economic infra-structure, insufficiencies in the national S&T system and poor coordination of the industrial policy process. (my translation)

Throughout the 2000s, the Brazilian national government increased its role in the Brazilian economy through the introduction of government programmes to support economic and social development, and approval of new laws aimed at supporting the country’s industrial activities. These changes represented a shift in the role played by the Brazilian state compared to the 1990s.

---

[89] Lastres (2007) acknowledges this.

Consistent with this, in 2004 a change in the national regulations was aimed at alleviating some of the dysfunctions in the local S&T systems, such as those identified by Corder (2004: 93),

> Brazil has the appropriate actors and a supporting infrastructure. However, cooperation among the actors and coordination by the state, and the capacity of firms to innovate are very restricted. There are also several factors that constrain the evolution of technical change towards consolidation of the Innovation System: low innovative performance of firms, relative isolation of universities, lack of definition of several research institutes and research centres, lack of an information system, lack of technology foresight, and lack of human resources capacities in building and management that would provide the state with the conditions to coordinate. (my translation)

The most important regulatory change was the 'Innovation Law' (Law nº 10.973/04) approved by national government in 2004. It represented an important effort to change the country's institutional setting with regards to local S&T activities.[90] It aimed to support, among others; i) improvements in public-private partnerships; ii) formation of strategic partnership between firms, and S&T institutes; and iii) engagement of researchers employed by public organisations in research projects with the private sector. Previously, researchers from public research organisations had to ask for permission from their employers to participate in collaborative research, and were not paid for collaboration with the private sector. Under the new Innovation Law permission was no longer required and researchers were remunerated (Pacheco, 2007; Pacheco and Corder, 2009). This law promoted technology policy design as discussed in Chapter 2, Section 2.2.2,[91] and especially engagement of the private and public sectors in the innovation network.

Also in 2004, government approved the creation of a new institute, the Brazilian Agency for Industrial Development (ABDI), which operates under the Ministry of Development, Industry and Commerce (MDIC) administration under a management contract. Its main aim is to provide support to MDIC in the formulation and implementation of industrial policies. ABDI also mediates between government divisions involved in policy formulation, such as MCT, FINEP and BNDES.[92] In 2005 government approved the creation of the National Council for Industrial

---

[90] Although the law was approved in 2004, it was formulated during the previous presidential administration (Pacheco, 2007).

[91] As discussed above, one technology policy channel is the imposition of new regulations that aim to improve the relations among actors and agents involved in technological activities and innovation.

[92] Fieldwork organisational interview.

Development (CNDI), to support the Brazilian President in formulating industry policy.

The creation of new public institutions throughout the 2000s suggests that the problem of institutional rigidity identified by studies of the Brazilian system of innovation, that is, the unwillingness of public organisations to adapt to the new needs promoted by changes in the innovation system, has persisted. It suggests also that these public organisations are likely to have overlapping aims, which may not contribute to improving the system. This is not to deny the efforts of central government to create an infrastructure that was intended to be better articulated, and with greater competence to set effective policies (addressing, for instance, the argument in Downs (1964) that public bureaux need to develop expertise and knowledge in particular fields to inform government policy makers during decision making). As discussed in Chapter 2, Section 2.3.1, changing path rigidities is costly and is a long term process that demands high levels of commitment from those involved.

With regard to national government intervention in the Brazilian economy, we find that the scope of some of the main public organisations increased through the decade of the 2000s. For instance, BNDES at the end of the 2000s was offering 30 special programmes, directed mostly towards industrial development, with 2 directed to industries that were identified as government priorities: i) the Programme to Support the Development of the Health Industrial Complex - Profarma, and ii) the Programme for the Development of the Software and Services in Information Technology Industries - Prosoft. Prosoft is of particular relevance for this thesis and is discussed in more detail in Section 3.2.3, where we address the Brazilian software industry.93 The BNDES also created a special programme to provide seed funding for start-up firms in partnership with the private sector. The Criatec Fund is managed by a private organisation and has supported 25 firms with an investment of some US$1M each.[94]

---

[93] www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Programas_e_Fundos/, accessed 05 January 2011.

[94] Fieldwork organisational interview. For a list of the firms that received Criatec support see http://fundocriatec.com.br/investidas.php, accessed 08 July 2011.

FINEP increased its public funding for the development of local innovation and at the end of the 2000s was offering more than 20 funding programmes, 7 of which were to encourage innovation in firms, such as: i) the FINEP Subvention programme which offers full or partial non-reimbursable funding; ii) the Zero Interest Programme which provides loans to small and medium firms at lower interest rates than the private banking system; and iii) Prime (Primeira Empresa Inovadora - the First Innovative Firm) which aims to create favourable financing conditions for start-up firms operating in high added-value sectors, to enable successful consolidation in the initial development stage of their investment.[95] Both the Zero Interest and Prime programmes are implemented in collaboration with regional organisations in the regions that benefit from the programmes.

The positive results of the efforts of national government to support the development of S&T activities in Brazil increased total investment in S&T activities from 1.3% GDP in 2000 to 1.57% GDP in 2010 (MCT, 2011: 3). Another indicator that shows positive results is increase in total investment in R&D which rose from 1.02% GDP in 2000 to 1.25% GDP in 2010, public investment in R&D which increased from 0.55% GDP in 2000 to 0.66% GDP in 2010, and private investment in R&D which rose from 0.47% GDP in 2000 to 0.59% GDP in 2010 (MCT, 2011). However, as already observed, the large share of public investment in R&D (compared to private investment), has been identified as one of the main fragilities of the Brazilian system that remains to be overcome.

Some efforts have been made to assess changes in innovation performance. The Brazilian Institute of Geography and Statistics (IBGE) in 2008 implemented the fourth innovation survey in Brazil, the Technological Innovation Research (Pesquisa da Inovação Tecnológica - Pintec). The survey follows the Oslo Manual (OECD, 2005) recommendations and the European Community Innovation Survey (CIS) 2008 format (Pintec, 2010a). Pintec 2008 shows that investment by the Brazilian government to create an institutional infrastructure to support R&D and innovation in Brazil, resulted in 38.6% of the firms included in the sample innovating in the period 2005-2008, including radical and incremental improvements (Pintec, 2010b:

[95] http://www.finep.gov.br/programas/prime.asp, accessed 29 June 2011.

37).[96] The survey differentiates between product and process innovations, and the degree of novelty. The survey shows that: i) 22.9% of industrial sector firms innovated in products and 4.1% were innovations that were incremental or radical in the national market (i.e. new or partially new practices or outputs for firms in Brazil); ii) 37.4% of services sector firms innovated in products and 9.1% of this innovation was radical or incremental in the national market; iii) 32.1% of industrial sector firms innovated in processes, and 2.3% of this innovation was radical or incremental improvements in the national market (i.e. new or partially new practices or outputs for firms in Brazil); and iv) 30.9% of services sector firms innovated in processes and 2.8% of these innovations were radical or incremental improvements in the national market.

The results for cooperation for the development of innovations (Pintec, 2010b: 49, Figure 6) show that the actors that showed the highest levels of cooperation for innovation were: i) digital information networks (78.7% for firms in the services sectors and 68.8% in the industrial sector); ii) customers (69.3% for firms in the services sectors and 68.2% in the industrial sector); iii) other areas within the firm (73.5% for firms in the services sectors and 61.5% in the industrial sector); and suppliers (55% for firms in the services sectors and 65.7% in the industrial sector). The lowest levels of cooperation with firms innovation activities were recorded for: i) research institutes and technological centres (16.1% with firms in the services sectors and 12% in the industrial sector); ii) universities and other higher education organisations (22.4% with firms in the services sectors and 13.4% in the industrial sector).

These results suggest that the dysfunctions in the Brazilian system of innovation, such as the low coordination between the supply and demand of knowledge produced in the country (as discussed by Corder, 2004), and low performance of innovative firms with regard to the degree of novelty of their innovations, are persistent problems that need to be overcome in order to establish a stronger system of innovation in Brazil.

[96] The CIS implemented in the UK in 2008 shows that 58.2% of British firms innovated during the period 2005-2008 (BIS, 2010), which demonstrates that the share of Brazilian innovative firms is considerably lower than advanced country firms.

3.2.4 Summary

The above shows that the Brazilian government tried to build an institutional set up to support and foster local S&T related activities from the 1950s. However, recurrent macroeconomic instability seems to have disrupted these institutional framework; policies aimed at economic stability have been prioritised over technological and industrial policies as if they were incompatible (Lastres, 2007). Two conclusions can be drawn from this observation. Firstly, there is a major problem at government level in Brazil which means that these policies are seen as antagonistic, when they should be included in the same agenda if sustainable economic development is to be achieved (Lastres, 2007; Pacheco and Corder, 2009; Suzigan, 1978). Lastres demonstrates that this conflict emerges also at the regional level, and shows that it is a strong cultural aspect of local and regional innovation systems within the Brazilian national system of innovation. Until this conflict is resolved, economic growth and development may not achieve the levels necessary for economic catching-up.[97]

Secondly, there has been very frequent creation of public organisations often with overlapping aims, which suggests difficulties for Brazilian organisations to adapt to and recreate themselves in the dynamic context of the evolution of innovation systems. This rigidity should be addressed by government, at various levels since it is evident in local, regional and national organisations (Pacheco and Corder, 2009). We can argue, therefore, that the system of innovation concept used to examine developed economies is not completely suited to an examination of S&T and innovation activities in Brazil. The concept assumes *ex-ante* the presence of systemic linkages in the interactions among the agents within the system of innovation, which seems still to be under construction in Brazil (Lastres, 2007). Systemic linkages remain to be developed in most ‘productive arrangements’ in Brazil, although regions performing under systemic arrangements are exceptions (Cassiolato and Lastres, 1999; Cassiolato *et al.*, 2003; Cassiolato *et al.*, 2008b; Lastres, 2007).

This thesis investigates the emergence and evolution of the Brazilian software industry to address these and other issues (Section 3.3). It addresses the software industry following a sectoral system approach (Section 3.3.1), to provide a sectoral background to the investigation of the Brazilian software industry (Section 3.3.2).

[97] Suzigan (1978) points out that this was already a problem in Brazil in the late 1970s, demonstrating that it has been a long-term structural frailty in the Brazilian policy formulation process.

3.3 The software industry and Brazilian software industry experience

This section discusses the emergence and development of the software industry in a developing country context, Brazil. Section 3.1 takes a sectoral systems approach, and investigates the main characteristics of the industry, highlighting the issues of technological and economic catch-up by developing countries in this industry. Section 3.3.2 discusses the Brazilian software industry, investigating its emergence (from the mid-1970s) and development until the late 2000s.

3.3.1 Overview of the software sectoral system of innovation

This section discusses the software industry following a sectoral systems of innovation approach, that is, it examines the particular and complex division of labour and knowledge specialisation, involving specific creation, use, diffusion and appropriation of knowledge, and learning processes (Malerba, 2002). According to Torrisi (1998: 39), software is: 'the production of a structured set of instructions, procedures, programs, rules and documentation contained in any types of physical support (tapes, disks, electric circuits or film) with the aim of making possible the use of electronic data processing equipment'. And according to Steinmueller (2004: 194), 'the software SSI [sectoral system of innovation] can be best understood in terms of interactions between the specific purposes for which software is created, the capabilities for fulfilling these purposes, and the means for commercializing results'.

Steinmueller claims also that a SSI approach emphasizes the role of systemic relationships involving knowledge exchange for innovation, particularly those that involve a close user-producer relationship, and improvement of public research organisations and networks within the industry.[98] However, none of these mechanisms is reliable in the context of the software industry, which leads to the conclusion that the software system of innovation has a 'deeper structure that, once delineated, can provide a meaningful interpretation of the division of labour in software creation' (Steinmueller, 2004: 207).[99]

---

[98] Tigre *et al.* (2011) investigate 6 software clusters in Brazil and Argentina, to explore some of these issues.

[99] Steinmueller (2004) provides a comprehensive discussion on the applicability of the SSI approach to the software industry, which is beyond the scope of this thesis and will not be pursued here.

Software is an intellectual and labour-intensive activity that deals with the codification of knowledge and information. Moreover, the production of software requires substantial tacit or experience-based knowledge in addition to codified knowledge (Brooks Jr., 1995; Grimaldi and Torrisi, 2001). For this reason, the cost of software production is high due to large investment in skilled labour and, in a developing country context, the additional costs of adequate machinery to support software production.[100] However, software replication and diffusion may involve low costs and, if successfully marketed as a purchased product, software producers can benefit from high returns once the high investment costs of the first copy are repaid. In effect, the potential for large profits in this industry will be realised if a large number of copies is sold because (constant) investment in the first copy is amortised over a larger number of copies and the marginal cost of making these copies is low.

The software industry's ability to appropriate the full value of its production is lower than industries that employ patents to protect their intellectual property. Although software often is protected by copyright, the enforcement of rights is less effective than with patents. One reason for this is 'the intrinsic difficulty in disentangling innovative and protectable expressions of original ideas, such as a "user graphic interface", from unprotectable ideas, such as an algorithm' (Grimaldi and Torrisi, 2001: 1428). This is an inherent limitation to the 'scope' of copyright which is limited to precise expression. In addition, because the costs of reproduction are low (even with various 'copy protection' schemes), a multitude of copyright infringing 're-publishers' emerge in almost every country and sell software at nearer to its costs of reproduction. However, the supposedly low appropriability in the software industry is compensated by other protection mechanisms, for instance, by the adoption of externalities associated with the use of highly diffused software (such as platforms and desktop applications); it is the nature of the product design rather than the means that is important from an appropriability perspective. The fact that designs can be protected through 'versioning' (with some level of enforcement), which reinforces the user's need to connect to the producer (to update the product), reduces the product appropriability problem. In addition, the production of software is related more to development than to basic research, and software that is more basic research

[100] Steinmueller (2001) provides a discussion on the barriers to catching up by developing countries in the ICT industry, some of these issues are discussed later in this section.

intensive tends to rely more on copyrights than those related to development activities (Grimaldi and Torrisi, 2001).

Software comprises both products and services, although the boundaries between the two are often blurred. The former relates to packaged software (generic solutions), customised software (produced out of necessity to improve productivity or find niches), and embedded software (software embodied in machines). The latter relates to such activities as consultancy, programming and training. Some software is developed internally by organisations, which usually involves the adaptation of packaged software to the needs of the organisation (Steinmueller, 2004). The production of software is commonly associated with the creative industries because it is intrinsic to software to involve novelty in every product or service provided; new software always aims to ‘produce new products or new ways of executing known tasks and functions’ (Torrisi, 1998: 41; Brooks Jr., 1995). Therefore, measuring product innovation in software is a challenging task, especially when software firms produce both products and services and cannot distinguish between them.[101]

Software can be categorised into two market segments, software packages and customised software, which are comprised of operating system software, programming languages, application tools and application solutions.[102] The level of technological complexity and R&D intensity differ among system software and application solutions (Torrisi, 1998). System software requires a much closer relationship between hardware and software manufacturers with the former often being the producer of the microprocessor. Hence, the roles of computer science and software engineering as fields of research are somewhat tangential to actual practice.

For instance, the origin of the software industry in the US was strongly related to basic research developed in universities to support the US defence industry,

---

[101] This is a general problem in the creative industries – effectively every new design is an ‘innovation’ in that it differs from existing designs and is meant to be produced in quantity. However, the process of design may, to some extent, be standardised and regularised as it is in the fashion industry, so that one is drawn to a level of differentiation in attempting to define innovation – e.g. the transformation of the athletics shoe to the trainer. A similar process occurs in attempting to understand software innovation and relies on the identification of new ‘application classes’ in packaged software and new ‘application domains’ in the case of software services and customised software.

[102] Operating systems are ‘the software that controls the operations of the computer system, and provides the “platform” upon which other functionalities can be constructed’; the application solution is the software that employs these functionalities (Steinmueller, 2004: 203).

especially after World War II up to the late 1970s (Mowery and Langlois, 1996).[103] Software and hardware development were indistinguishable in the early stages of the software industry (Steinmueller, 1996) and US federal investments in R&D and procurement for the development of hardware to support the military industry indirectly supported the country's software industry.[104] Mowery and Langlois (1996) discuss the great importance of tie formation between the public and private sectors during that period, through the purchase by universities of computers.[105] This contributed to the creation of computer science as a new academic discipline, and US universities played an important role in the diffusion of innovation in software:

> Ph.D. graduates of these [top US] universities found employment in senior positions in firms such as Silicon Graphics, Microsoft, and Sun Microsystems. The faculty at many of these institutions also entered into formal and informal consulting relationships with private firms, and others were directly involved in the foundation of such important hardware and software firms as the Carnegie Group, Ingress, and Thinking Machines. (Mowery and Langlois, 1996: 955)

Although the US government strongly supported the emergence of the software industry, Steinmueller (1996) stated that there is no 'natural' industrial structure for software production and that the structure and evolution of a nation's software industry depends upon particular historical and institutional events. Steinmueller claims also that because the specifics of history, institutions and participants are important, a study of the software industry's evolution must begin at the national or regional level, rather than in the 'global market' (Steinmueller, 1996: 18). This suggests that investigation of the software industry should combine a sectoral and regional systems of innovation approach.

Localised historical and institutional events are relevant to explain the development of the software industry within a country, which supports understanding of how, for example, the private and public sectors interact in this industry. In addition, Grimaldi and Torrisi (2001: 1428) state that the complexity of software products and their innovative activities require different types of S&T knowledge for software

[103] From the mid 1970s US government expenditure was directed more to applied research (Mowery and Langlois, 1996).
[104] The US Department of Defense was the only federal government level department with substantial funding for basic and applied research for military purposes, that developed potential applications for many industrial sectors. The software industry benefited from this policy.
[105] 'Defense-related agencies funded more than 50% of academic computer science R&D from fiscal 1977 through the mid-1980s, and defense-related support for applied computer science research grew rapidly after fiscal 1983' (Yudken and Simons, 1988; quoted in Mowery and Langlois, 1996: 952).

development. This demands from firms different combinations of internal competencies, knowledge and experience, with external sources of knowledge, which happens through the creation of ties with supporting organisations such as universities, specialised suppliers, and users. The creation of such ties brings the fore the sectoral role in the formation of inter-organisational networks in the software industry.

For instance, Grimaldi and Torrisi analysed five Italian software firms in the late 1990s and found that most external collaborations from these firms were commercially based.[106] However, some ties aimed at the exchange of technical as well as commercial knowledge. External ties differed according to firm size, product complexity, and the incentives for knowledge codification. Therefore, although one of the main characteristics of the software industry is the use of tacit and scientific knowledge, the codification of knowledge to improve internal development activities is a driver of the creation of external ties. The incentives for the creation of external ties also differed depending on firm size and type of product to be developed (Grimaldi and Torrisi, 2001: 1436).

The software sectoral characteristics discussed above introduce various issues to the discussion of the engagement of developing countries in the global software industry, highlighting the importance of leapfrogging and technological catch-up.[107] The main characteristics of the software industry, such as intensive skilled labour, low fixed investment compared to traditional sectors, and high possibility of imitation, suggest that developing countries might have a comparative advantage in catching up with the developed economies. This argument is based on classical economic theory and assumes that developing countries have an availability of cheap skilled labour compared to the developed economies, which could be a comparative advantage for the engagement of the former in the international ICT industry. Gaio (1992: 93) argues against that proposition claiming that:

> the science-base nature of IT, associated with an exceptional technological dynamism, a labour-saving bias and pervasive impacts on product and process innovations, would tend to generate negative externalities upon

[106] Grimaldi and Torrisi acknowledge the limitation imposed by small firm sample size, on generalisation. However, they suggest that their evidence illustrates some features of the industry that might shed light for future research on this industry.

[107] According to Steinmueller (2001: 94) leapfrogging is the ability of a country to bypass ‘some of the processes of accumulation of human capabilities and fixed investment in order to narrow the gaps in productivity and output that separate industrialised and developing countries’.

> LDCs [Later Developing Countries], such as a loss of competitiveness in international markets, a deepening of dependency on foreign technology and the generation of unemployment with structural characteristics (…) Thereby, an analysis based on static comparative advantages does not appear to outline the appropriate strategy for promoting sustained growth.

Along similar lines, Steinmueller (2001) argues that leapfrogging by developing countries in the ICT industry, including software firms, would face the following barriers. The requirement for: i) high levels of absorptive capacity by local firms, so that imitation would lead to innovation; ii) complementary technological capabilities, for example, in the efficient use of mechatronics; iii) solutions to common shortages in the number of skilled programmers; iv) the ability to create reliable and internationally reputed brands; and v) solutions to recurrent problems of unreliable electrical power supply and environmental conditions of high humidity and temperature. Tigre *et al.* (2011: 21) claim that it is not only technical knowledge that is required for a catching-up process:

> to participate in international networks, it is not enough to know programming and systems analysis; proficiency in English and other languages is also required. This includes not just linguistic abilities per se, but also the ability to understand specific cultural codes of relationship and communication. Workers have to adopt the quality standards of clients, meet deadlines and inspire confidence in their partners abroad. These cultural abilities are considered to be even rarer than technical abilities.

Steinmueller (2001: 205) acknowledges that innovation in developing countries could be achieved through the recombination of existing knowledge in the ICT industry, which would lead to opportunities in software for local and vertical markets, since innovation in ICT applications requires understanding and use of localised knowledge. However, localised knowledge is ‘likely to reside in smaller, specialized companies that do not have global reach’ (Steinmueller, 2001: 205). Therefore, the challenge for developing country ICT firms to enter global markets is greater. This is comparatively less of a problem in very specialised and innovative software producers who enter the global market often through licensing of their product to established companies. However, global insertion is more problematic in the case of broader applications (such as ERP platforms), in which the problem of building brand is considerably larger. This is because such markets are vertically integrated, standardised and largely concentrated and, therefore, dominated by a few, well-established, large firms. Independent firms established in developing countries find it difficult to compete with these large firms, firstly because of the latter’s dominance in the diffusion of applications, and their reputation. For instance, Britto *et al.* (2007: 10) claim that there has been an increase market concentration in the Brazilian software industry, following:

> the increase of international competition and the sophistication of consumer demands - elements that tend do reinforce the importance of availability of financial resources and distribution channels - contribute to this process, making harder the maintenance of market shares. To local firms the impacts of these tendencies might be disruptive: large users tend to adopt a risk averse purchasing attitude that favors the selection of established foreign suppliers, whereas small and medium sized enterprises (SMEs) are not willing to pay a premium for the domestic firms' unique knowledge.

Secondly, independent firms often follow the strategy of adopting well diffused technologies, so that they can benefit from the reputation already established by large application producers (Shapiro and Varian, 1999).

Considering these issues, we can point to policies in developing countries that seek to overcome at least some of these barriers, so that catching-up with the leading countries can be achieved. For instance, Indian government investment in skilled IT labour training in universities and other educational organisations was aimed at solving the shortage of IT skilled labour force. Another common practice is the creation of science parks, such as in India and China, with the aim of foster university-firm interaction, following the argument that ICT scientific disciplines are extremely relevant for knowledge creation and development in the industry (Britto *et al.*, 2007; Veloso *et al.*, 2003).

This section discussed the main characteristics of the software industry and highlighted important issues involved in how its development can be fostered. Developed countries' experience in the software industry differ from that of developing countries, and the former leads the industry at global level (Veloso *et al.*, 2003). Section 3.3.2 investigates the Brazilian software industry.

3.3.2 The Brazilian software industry: emergence and development

We discuss the emergence and development of the Brazilian software industry across two periods. Firstly, the emergence up to the early 1990s when internal market protection ceased (Section 3.3.2.1); secondly, industry development up to the late 2000s (Section 3.3.2.2) when local firms were more exposed to international competitions, and government policies to support industry development was based on different strategies compared to the previous period.

3.3.2.1 Emergence: the mid 1970s to early 1990s

The emergence of the Brazilian software industry was motivated by the national government IT policy implemented in the early 1970s (Araújo, 2011), and formally consolidated in 1984 with the ‘Informatics Law’ (Law n° 7.232). This policy targeted the development of the local IT industry, economic growth and indigenous technological development in local firms and higher levels of industrialisation through import substitution arrangements in line with internal market protection for local IT firms. Approval of the ‘Informatics Law’ coincided with the beginning of Brazilian economic liberalisation, and guaranteed protection for the local IT market for the next eight years (Gaio, 1992: 106; Pacheco, 2007; Roselino, 2006).

The informatics policy was aimed at development of the local hardware industry, especially telecommunications and minicomputers. Development of the local software industry was complementary to hardware, with investments directed mostly to the production and trade of packaged software.[108] The most important policy mechanisms to support the local software industry were: i) government procurement; ii) strong regulation over imports of software solutions by Special Secretariat of Informatics (SEI);[109] and iii) SEI approval for manufacturing projects related to micro computers using operating systems developed by local firms. The regulation required registration of all computer programs produced and traded in the country with SEI, which also controlled imports, allowing them only if no similar software was being produced locally (Gaio, 1992; Roselino, 2006). However, the import regulation was not completely effective because SEI had very little control over MNCs intra-firm operations, and by the mid-1980s MNC subsidiaries were responsible for most of Brazil’s trade in imported software, about 80.3% (Gaio, 1992: 111). In addition, there was easy replication (piracy) of imported software in the local market, which was beyond government control (Roselino, 2006) and

[108] Gaio (1992) states that one of the reasons for the government focus on packaged software was the successful experience of the USA in this market niche, and replication of this strategy seemed useful.
[109] This was associated with the Software Law (no. 7646/87, approved in 1987), which required there to be no equivalent software produced nationally for the registration and commercialisation of foreign software for small and medium equipment (Roselino, 2006: 115).

provided even more effective competition for local products than a legitimate and higher cost source.

Under the arrangements of the ‘Informatics Law’, in 1987 national government implemented a policy to explicitly protect the national software industry. It continued the import restrictions aimed at developing indigenous technologies by local firms, and allowed software imports only if no similar software was produced in the country. The software import restrictions were not backed by direct incentives for the development of the industry. However they did support the emergence of a Brazilian software industry (Roselino, 2006).

The informatics policy was not quite as effective for supporting the local software industry as it was for supporting the production of microcomputers. The production of packaged software requires a close user-producer relationship, which did not occur because local users gave priority to purchasing imported packages, mainly based on their better reputation and settled technologies compared to those of local products.[110] In addition, the production of packaged software is characterised by high cost and continuous investment in research for redesign, customisation and technical support, all economically infeasible for local small firms. Most local firms were small and considered these investments too risky.[111] Hence, although they were aware that tackling market demands would lead to international competitiveness, they preferred a defensive and short-term strategy. They invested instead in software applications. However, this software market niche was not sufficiently dynamic to guarantee sustainable growth of the local software industry (Gaio, 1992). The local packaged software industry did not develop at a suitable pace based on demand from the local minicomputer industry, which in 1986 was largely met by imported software. As a result, ‘the informatics policy tended to focus on the promotion of the supply of local products, while not dealing with the diffusion process’ (Gaio, 1992: 110).

[110] Steinmueller (2001) points out that the issue of developing an ‘own brand’ is one of the main challenges to countries that try to leapfrog.

[111] Corder (2004: 121) discusses the Brazilian financial system and shows that the investments in innovation activities by private credit are historically problematic in Brazil, among other reasons because of the inherent uncertainty of innovation activities, Brazil’s economic instability, and low demand for private credit from local firms which often preferred public finance given the conditions imposed by private lenders.

In 1991, under economic liberalisation, national government approved the new Informatics Law (8.248/91), shifting from the previous internal IT market protection policy to fiscal incentives for R&D activities. The most important fiscal incentive defined by the law was the 15% exemption on industrialised goods taxation (IPI) and the 2% IPI exemption for components; firms were required an accompanying investment of 5% of their total revenue in R&D activities (performed in house, in a teaching and research organisation or in a S&T programme pre-defined by the Brazilian Ministry of S&T-MCT) (Garcia and Roselino, 2004).

The change in the law fostered the creation of private, non-profit ICT research institutes, which in some cases were founded by MNCs already established in the country (Ritz, 2008). The research centres founded by MNCs performed R&D activities almost exclusively for their founders; it was a mechanism used by MNCs to benefit from the law using specialised knowledge that already conformed to MNCs' demand (Garcia and Roselino, 2004; Stefanuto, 2004). According to MIT-Softex (2002: 19), from 1993 to the end of 2001 the Informatics Law benefited 428 firms, with R&D resources to a total of RS$2.9B in this period; 63% was performed by firms and 33% by firms in partnership with research institutes. The majority of R&D investment exploiting the provisions of the Informatics Law was directed to hardware development, and MNCs were the main beneficiaries.[112]

In the early 1990s, the Brazilian software industry was failing in its technological catch-up attempts. One of the reasons was the strategy implemented by national government of investing in the packaged software market, which was already showing signs of maturity and was organised under an international oligopolistic market structure. However, the complementarities of software development in the telecommunication hardware industry proved very important for the development of the Brazilian software industry in the 1990s. Most internal software production was performed by large IT firms, including CPqD, the Telebrás (the telecommunication state-owned firm) research centre. As already mentioned (Section 3.2.3), with economic liberalisation the MNCs took over some former government owned monopolies. One of the consequences of Telebrás' privatisation was that CPqD lost

[112] The case of the Scientific and Technological Park of the Pontifical Catholic University of Rio Grande do Sul (TECNOPUC) demonstrates that MNCs benefiting from the Informatics Law implemented long-term projects through localised R&D laboratories, which involved close interactions with the University and extensive training of undergraduates and postgraduates (Araújo and Teixeira, 2008).

most of its guaranteed procurement and redirected its investments to software. This followed the centre's assessment that CPqD had developed high technological capabilities for software development because of the software embedded in telecommunications hardware; and in 1991 80% of telecommunications hardware was composed of embedded software (Stefanuto, 2004).[113] CPqD had a central role in the formulation of the Softex Programme, as discussed below.

3.3.2.2 The Softex Programme and policies supporting the local software industry

In 1993, in the new economic liberalisation context, government implemented the Softex Programme, a national programme to support Brazil's software exports, with the aim of achieving 1% of the global software market by 2000. This programme was created under a comprehensive national project to support the Brazilian IT industry, the Informatics Strategic Development Project (DESI).

DESI included two other programmes: i) the National Research Network (RNP) which aimed to link the country's scientific community through the Internet; and ii) the Thematic Programme in Computing Science (PROTEN-CC), which aimed to foster cooperation between the private sector and computer research organisations (Roselino, 2006; Stefanuto, 2004).[114] The formation of networks, therefore, played a crucial role in the project. DESI's creation followed the assessment that the core organisations for local scientific and technological development needed to improve their cooperation (Stefanuto, 2004).[115]

Although the implementation of the Softex Programme occurred under the DESI project, it was originally developed within CPqD by a group of its researchers. Because of the centre's accumulated expertise with embedded software and strong relationship with the local research university (State University of Campinas), the idea of having institutional support for interaction between the private and public sectors, and a local research university involved in the creation of knowledge related to ICT, seemed a good idea to foster the country's software industry.[116] Hence, the Softex Programme proposal created by CPqD took account of CPqD experience, and was implemented by national government. This type of policy programme to support

---

[113] Pilot fieldwork interviews number 7 and 8.

[114] Further discussion of these two programmes is beyond the scope of this thesis. For detailed discussion of them see Afonso *et al.* (1999).

[115] Stefanuto (2004) conducted a study on the Softex Programme for 1992 to the early 2000s and most information about the programme's formulation, aims and implementation are based on his findings.

[116] Pilot fieldwork interviews numbers 4, 7, 8 and 9. Brazil fieldwork interview numbers 4 and 8.

and foster interaction between the private and the public sectors with the high involvement of research universities, had been implemented in developed and developing countries (e.g. in India, MIT-Softex, 2002). In India, the aim was to replicate successful industrial development experience in the developed economies.

The Softex programme created regional networks and a Softex Nucleus was established and linked to local firms through affiliations. The programme's rationale was that close geographical proximity among firms and universities would foster innovation in firms, and lead to higher market performance. According to interviewees, the programme's formulation deliberately conformed to a system of innovation approach.[117]

The Nucleus aimed to support exporting by local software affiliated firms through the provision of technical and managerial support, and international market information. By the end of 1993 Softex had 13 Nuclei, covering almost all regions within the country.[118] The establishment of a Nucleus in a region required that: i) the region was host to a research university offering post-graduate degrees in computing science; ii) the region could demonstrate an orientation towards the development of software (e.g., through the presence of established firms); iii) the region had to host a technological park (or have a proposal in place for the creation of a park); and iv) the local government would contribute funding for the Softex Nucleus (Stefanuto, 2004).

Once a Nucleus was established, the Softex programme committed R$1M through CNPq scholarships for firms developing projects related to exports, which included: i) software development; ii) human resources training; and iii) financial support for participation in international fairs. The Nucleus provided juridical and marketing consultancy, and updated hardware to support software development, which was shared by affiliated firms. In 1996, the Softex Programme created Genesis Centres, which were incubators for software start-ups. One of the aims of these incubators was to augment knowledge in entrepreneurship for start-up managers, who often were recent graduates from ICT related disciplines. Degrees in computing science in Brazil were generally science oriented, and did not include training in entrepreneurship (Stefanuto, 2004). This suggests a lack of interest of local research

---

[117] Pilot fieldwork interviews number 4, 7 and 8.

[118] The most favoured region was the Southeast region with 6 Nuclei, followed by the South region with 4, the Northeast with 2 and the Central-West with 1 (this last in the capital, Brasília).

universities in engaging with the private sector IT firms. Local ICT research university departments focus only (or mostly) on academic knowledge with low involvement from the private sector.[119] The Softex Nucleus and Genesis Centres merged into a single organisation in 2002, following an assessment that they were competing; the new organisation is known as the Softex Agent.

The Softex programme failed in its original aim to have a 1% global share of the software industry by 2000, or an estimated US$2B. By 2000 Brazilian software exports had reached US$100M, significantly lower than the target (Britto *et al.*, 2007; Stefanuto, 2004). There are several reasons for this failure. Firstly, the local software firms concentrated on development for the internal market, which had not been exploited and so demand was good. Secondly, Brazilian firms had failed to develop packaged software and directed investment to vertical software markets. Those markets show intensive user-producer interaction, reinforcing the role of the local market which was more accessible. Thirdly, the local firms supported by the programme were often start-ups or micro firms, which did not have the necessary technological capabilities to develop software products or services that could compete with international firms with reliable and well established technologies. Fourthly, there was no ‘client-led drive’, as mentioned by Britto *et al.* (2007: 4):

> rather than to find first who are the clients that might be attended and then sorting out how and what products could be sold to them, the drive was put behind pushing what was available, without a focus in which segments and which markets could be properly exploited.

Finally, the English language was a barrier to international market penetration (Roselino, 2006; Stefanuto, 2004). Thus, Brazilian firms did not manage to overcome some of the important barriers to leapfrogging in the ICT industry highlighted by Steinmueller (2001) and discussed above.

However, the Softex programme played a central role in creating software networks in different regions within the country through the creation of new software firms. Also, it was very relevant for political and institutional interaction in the industry (Araújo and Meira, 2004; Roselino, 2006; Stefanuto, 2004).[120] For instance, between 1991 and 2001, the software industry increased its share in national GDP from

---

[119] This issue is addressed in Chapters 4, 6 and 7. Pilot fieldwork interview number 11. Campinas fieldwork interviews numbers 1, 2, 11, 12, 18, 25, 27, 44, and 46. Recife fieldwork interviews numbers 10, 12 and 25.

[120] In the early 2000s there were 22 Softex Agents distributed in 12 Brazilian states (Stefanuto, 2004).

0.27% to 0.71%, and became the most significant market in the IT industry (MIT-Softex, 2002). This percentage translates into 879 software national firms active in the country in 2002 (see Table 3.1) (Roselino, 2006). Table 3.1 highlights that Brazilian firms performed in the lower added value niches of the industry, reinforcing the argument that development of technological capabilities in software development is a long term goal. And, although software is pervasive and a relatively easy product to imitate, the development of absorptive capacity by software firms is not a straightforward achievement, although essential for the reproduction of knowledge created externally to the firm.

Table 3.1 Brazilian software producers, national and foreign firms - 2002

Type of activity/ type of firm	Private national firms	Public national firms	Foreign firms	Total
Services in informatics	222	7	20	249
Software services- low added value	368	13	36	417
Software services- high added value	140	-	11	151
Development and commercialisation of software product	149	-	29	178
Total	879	20	96	995

Legend:
Services in informatics= consultancy in hardware, maintenance, and commercialisation of equipment.
Software services- low added value= internet services, creation and maintenance of database, outsourced data processing, and technical support.
Software services- high added value= Customised software (analysis, project, programming, tests, implementation and documentation), project development, and database modelling.
Development and commercialisation of software product= development and production of software ready to use (including software for customisation), commercialisation and licensing.
Source: Adapted from Roselino (2006: 150-151).

With regard to the Softex Programme creating software networks within the country, Britto and Stallivieri (2010) find that 30 Brazilian regions were producing software in 2006, 17 of which hosted a Softex Agent,[121] and involved a total of 2,841 software firms. The outlier regions in terms of number of firms were mainly Brazilian state capitals, such as São Paulo with 652 firms, followed by Rio de Janeiro with 238 firms and Belo Horizonte with 201 firms. These cities are all based in the Brazilian

121 http://www.softex.br/_agentes/lista.asp, accessed 14 January 2011.

Southeast region, the wealthiest and most dynamic industrial region in the country,[122] corroborating the findings from other studies of the software industry in Brazil (such as, MIT-Softex, 2002; Roselino, 2006; Stefanuto, 2004).

Other public incentives were implemented to support the development of the local software industry.[123] For instance, in 1993 alongside the Softex Programme, the Brazilian Programme for Quality and Productivity (PBQP) was implemented and designed a special division for the software industry, PBQP-sw.[124] The programme aimed to support the adoption of norms, methods, techniques and tools related to the quality of software engineering to promote improvement in software processes, products and services.[125] The programme was formulated by a commission of volunteers from public and private organisations, including firms, universities and research institutes, as well as government authorities (such as SEPIN, the MCT Secretary for Policy in Informatics).

The Brazilian software industry is also supported by Prosoft, a special programme set up in 1999 by the Brazilian Development Bank (BNDES), to help the software industry.[126] Prosoft benefits local software firms with BNDES loans under special conditions (no requirement for real guarantees), which are accessible to small and medium firms (but not start-ups); the establishment of corporate governance in firms applying to Prosoft is a requirement of the Bank.[127]

Prosoft has three funding mechanisms. Prosoft Empresa (Prosoft Enterprise), which provides funding up to about US$640K,[128] through funding or land value subscriptions for investment and business plans for software producing firms and firms offering IT related services. Prosoft Empresa has two supporting mechanisms, direct (where firms can hire consultancy services from Softex, which submits the application to BNDES without the charges for the BNDES Commission of Studies)

[122] http://www.ibge.gov.br/home/, accessed 14 January 2011.
[123] Araújo (2011: Box B1 and Box B2) provides a detailed list of policies implemented by the Brazilian government that relate to the support of the local software industry.
[124] PBQP is Programa Brasileiro de Qualidade e Produtividade.
[125] http://www.mct.gov.br/index.php/content/view/47694.html, accessed 07 July 2011.
[126] All information on the Prosoft programme was collected from the programme's website. The programme has an extensive and complex regulation which is not discussed in detail. For detailed information see: http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Areas_de_Atuacao/Inovacao/Prosoft/index.html, accessed 07 July 2011.
[127] Fieldwork organisational interview.
[128] Conversion rate of 1,558 available from the Brazilian Central Bank, available at: http://www4.bcb.gov.br/pec/conversao/Resultado.asp?idpai=convmoeda, accessed 07 July 2011.

and indirect (where firms submit applications directly to the bank, but have to pay the fees of the BNDES Commission of Studies). Prosoft Empresa supports a wide range of activities, including: i) investments in new machines and equipments; ii) investments in infrastructure; iii) expenses related to the improvement of managerial and technological capacities, training and certification; and iv) investment in development and research for new products, process and services.[129] Since its creation (1999) until the year of data collection (2009), 66 software firms had contracts issued under the ‘Prosoft Empresa’ programme, 7 new firms were already approved for benefits and 30 proposals were being considered.[130]

The second Prosoft funding mechanism is Prosoft Comercialização (Prosoft Commercialisation), which provides funding for acquisition, in the Brazilian market, of software and correlated services developed in the country, exclusively through financial institutions accredited by the Bank. Firms that operate in the country as well as public authorities can benefit from this programme. The lines of the programme comprise total or partial licensing of intellectual property rights, and total or partial acquisition of intellectual property rights, of national computing programmes developed by suppliers that are accredited by the Bank.

The third Prosoft funding mechanism is Prosoft Exportação (Prosoft Exports), which has two funding means. Firstly, BNDES Exim Pré-embarque, which provides funding for the development of software and IT services aimed at exports (but pre-export activity). Minimum funding is US$200M and only firms that have been established for at least 5 years can apply for this, and are required to have exported a minimum of US$200M in *software* or IT services in the 24 months previous to the Consultation stage with the Bank. Secondly, there is BNDES Exim Pós-Embarque, which supports firms that have already concluded the exports.

The Informatics Law was revised in 2001 (Law 10.176/01) and again in 2004 (Law 11.077/04). The most relevant change was the requirement that a percentage of firms’ R&D activities had to be performed in less economically favoured Brazilian regions (i.e., North, Northeast and Central-West). The new law aims to foster

[129] Software producing firms and firms offering IT related services include: firms that develop packaged software, embedded software, customised software products and components, in addition to services in IT, such as consultancy, development of customised software, training, support and maintenance, outsourcing and Business Process Outsourcing, including call centres and contact centres.

[130] Fieldwork government interview.

regional development through the development and growth of the local IT industry in economically and socially disadvantaged regions. One of the arguments for this is that the pervasiveness of software could support the development of other industries in these regions. The non-profit private research centres located in those regions have benefited greatly from this change in the law. For example, the number of employees in the Recife Center for Advanced Studies and Systems-CESAR, which is based in Porto Digital (Pernambuco State) in the Northeast region, almost doubled in the period 2004-2007, and in 2006 69.9% of its total income was from resources available under the new Informatics Law (Ritz, 2008).

In addition to fiscal incentives, the Brazilian national government employs direct policy instruments to foster firm innovations, in the IT and other industries. As mentioned in Section 3.2.3, the Brazilian Innovation Agency (FINEP) provides non-reimbursable grants to support firms' research through special calls. FINEP runs the Zero Interest Programme (since 2004), to support small and medium firms through low interest loans and has implemented the Prime Programme, to support start-up firms.

FINEP manages the Sectoral Funds, and CTInfo is the Sectoral Fund devoted to the development of the local ICT industry, including software. The funding source comprises a (minimum) 0.5% of the total revenue of firms that develop or produce informatics and automation goods and services in Brazil and benefits from fiscal incentives under the Informatics Law.[131] The funding allocation framework is through open calls that channel investments according to priority knowledge areas.

Another initiative implemented by Softex in 2003 is the MPS.br Programme (Programme for the Brazilian Software Process Improvement), in which the following organisations were involved in the formulation of the programme in addition to Softex: the Alberto Luiz Coimbra Institute – Graduate School and Research in Engineering at the Rio de Janeiro Federal University (COOPE/UFRJ); the Renato Archer Information Technology Centre (CTI/CenPRA); the Recife Center for Advanced Studies and Systems (CESAR); SoftexRecife; the Brazilian Technical Standards Association (ABNT); and the Informatics Company of the State of Paraná

---

131 http://www.finep.gov.br/fundos_setoriais/ct_info/ct_info_ini.asp?codSessao=1&codFundo=8, accessed 07 July 2011.

(CELEPAR) (Britto *et al.*, 2007).[132] The programme is sponsored by the Brazilian Ministry of S&T (MCT), FINEP, and also the Inter-American Development Bank, to 'improve [the] software process in Brazilian organizations at reasonable costs' (Weber *et al.*, 2007: 111). MPS.br is strongly based on Capability Maturity Model Integration (CMMI) certification, and related to the increased relevance of CMMI in the country, meaning that firms awarded CMMI certification benefited from access to public calls, and greater credibility in the market. Because of the costs involved in CMMI implementation, the Brazilian government wanted to establish a similar certification process that would give credibility to local firms, and support their development activities. The programme aims to support Brazilian local firms to improve their software development processes and to support firms' professional management. MPS.br has seven stages, from A to G, where G is the first and lowest level and A the seventh and highest level (CMMI has 5 stages, stage 1 is the first level and stage 5 is the highest level) (Weber *et al.*, 2007). Taking into account that the majority of local software firms is composed by micro and small firms, MPS.br aims to adjust the well diffused CMMI certification process to the needs of local firms. The MPS.br programme assessed that it was necessary to create two new intermediate stages so that local firms could progress within seven rather than five stages, based in the argument that local firms were likely to struggle to advance along only five stages.[133]

Softex manages the programme and firms associated with Softex can benefit from subsidies of 40% for the MPS.br certification process.[134] A survey implemented by iMPS,[135] showed that during the period September 2005 to November 2010, 250 firms had been assessed by the MPS certification process, mostly micro or small firms (Travassos and Kalinowski, 2011). According to these authors, most firms that adopted MPS achieved higher customer satisfaction levels and higher productivity and capacity to develop more complex projects compared to before MPS adoption (they also showed better development than firms still in the implementation stage).

[132] As discussed in Chapter 2, Section 2.2.2, the engagement of these organisations in the MPS.br project highlights the relevance of networks within the government aimed at increasing knowledge and expertise in specialised fields.
[133] Campinas fieldwork organisational interview.
[134] Campinas fieldwork organisational interview.
[135] iMPS (Informações para Acompanhar e Evidenciar Variação de Desempenho nas Empresas que Adotaram o Modelo MPS') is information collected for the assessment on firms awarded MPS certification.

These results suggest that MPS.br is fulfilling its aim to support local firms to implement best practice.

In 2004 another initiative was introduced by national government to support the development of the local software industry, the Sectoral Integrated Project for Software Exports and Related Services (PSI-sw).[136] The project was created in a partnership between the Brazilian Trade and Investment Promotion Agency (APEX) and Softex, and under the new national policy implemented in 2004 (PITCE) when software became a government priority.[137] The aim of the project is to promote and improve the internationalisation of Brazilian software firms and firms that develop IT related services. The project has been renewed several times since its creation, and is established until 2012. Firms wanting to benefit from PSI-sw funding do not receive it direct from APEX, the organization that manages the funding. Firms must submit proposals through associations, which become responsible for managing the finance.

Since 2000, several national government initiatives have been implemented to support, directly or indirectly, the local software industry. Some of these initiatives support the interactions (through the creation of formal or informal ties) among components of the innovation system. In addition, national government has implemented regulations enforcing connections among some of the actors in the innovation system. For instance, only firms that are associated to Softex can benefit from the incentives for MPS accreditation and submit applications to BNDES Prosoft-Empresa free of charge.

There is no single indicator that can be used to assess whether the government initiatives discussed above have translated into improvements in the performance of Brazilian software firms. However, according to the Brazilian Association of Software Producers (ABES), Brazil's ranking in the global market increased from the 15th in 2005 to 11th position in 2010.[138] This suggests that national efforts to support the Brazilian software industry are showing positive results.

Also, according to Pintec (2010b: 73; Table 1.1.6) innovation by firms involved in the development and licensing of computing programmes and other IT services are

[136] PSI-sw is Projeto Setorial Integrado de Exportação de Software e Serviços Correlatos.
[137] http://golden.softex.br/portal/desenvolvimento/_psi-sw/psi2007-2009.asp, accessed 07 July 2011.
[138] http://www.abes.org.br/templ3.aspx?id=306&sub=650, accessed 07 July 2011.

well above the average for innovative firms (38.6%), at 58.2% and 46.1% respectively.[139] This trend is confirmed if we compare their innovative performance with performance in other industries, such as the extractive industry (23.7%) and transformation industry (38.4%).

3.4 Conclusions

This section summarises the points discussed in this chapter. We provided an overview of the Brazilian industrialisation process highlighting the establishment of the main public organisations created (Section 3.2). We showed that the institutional framework created by the national government has not always received the same level of attention, especially in the early 1990s, and that the long term economic instability present until the mid 1990s prevented government from focusing on investments in S&T at the level required for economic development and technological catch-up.

We also discussed the emergence and main characteristics of the software industry following a sectoral system of innovation approach, and the emergence and evolution of the Brazilian software industry. We found that there has been increasing effort through government initiatives to support the industry, either directly (e.g. Prosoft by BNDES) or indirectly (public funding organisations that provide funding to several industries).

Chapter 4 addresses the emergence and development of two Brazilian regions active in the software industry, Campinas and Recife.

[139] The share of innovative firms in service related industries was above the average, i.e. 46.5%, showing that the innovative performance of other IT services firms have followed the overall trend. The results of Pintec 2008 are not comparable with Pintec 2005 with regards to software activities, because the industry classification changed during this period.

CHAPTER 4 – A TALE OF TWO SOFTWARE REGIONS: CAMPINAS AND RECIFE

4.1 Introduction

Chapter 4 introduces and provides historical evidence on the structure of the two networks investigated in this thesis. Based on the argument that there is a need for a deeper understanding of the emergence and evolution of networks through an examination of network governance (Chapter 2, Section 2.4), Chapter 4 examines the regional history of the emergence and development of the software industry in the Campinas and Recife networks. These networks are based in Campinas, a country city located in the São Paulo State (Brazilian Southeast) and Recife, the capital of Pernambuco State (Brazilian Northeast). These regions show great disparities in their socio-economic and scientific systems.

The Southeast region share of Brazil's population was 42.1% in 2010 (IBGE, 2010b) and its GDP in 2008 was 56.0% (IBGE, 2008). The São Paulo State share of Brazil's population was 21.6% in 2010 (IBGE, 2010b) and its GDP in 2008 was 33.1% (IBGE, 2008). These indicators provide evidence of the economic potential of São Paulo.[140] Per capita GDP for Campinas in 2008 was US$11.9K compared to the national average of US$6.8K.[141] The population of the Campinas City was 2.6% of total São Paulo State population in 2010, and 0.6% of the total Brazilian population (IBGE, 2010c).

The strong economic and industrial dynamics of São Paulo State and Campinas city are combined with a strong and well established regional scientific system. The São Paulo State Research Foundation (FAPESP) is one of the most important public research funding organisations in Brazil, with an estimated budget of US$402M in 2009.[142] Campinas is geographically close (100km distant) to São Paulo City, the capital of São Paulo State, and one of the most economically dynamic cities in Brazil. Campinas city is host to one of the best reputed public research universities in Brazil, the State University of Campinas (Unicamp), which conducts research in

[140] The country is comprised of 27 states (Brazilian Institute of Geography and Statistics-IBGE).
[141] Exchange rate used the Brazilian Central Bank conversion rate of R$1 = US$2.337, for 31 December 2008. Available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, last accessed in 16 June 2011.
[142] Campinas fieldwork organisational interview.

several disciplines.[143] There are also several private teaching universities in Campinas.

The Northeast region accounts for a much lower share of national GDP compared to the Southeast region, 13.1% in 2008 (IBGE, 2008); and its Northeast of Brazil's population was 27.8% in 2010 (IBGE, 2010b). The Pernambuco State's share in Brazil's population was 4.6% in 2010 (IBGE, 2010b), and its share of the GDP was 2.3% in 2008 (IBGE, 2008). These indicators show that this region is economically lagging behind the Southeast region and São Paulo State. Recife's per capita GDP was US$6.2K in 2007 compared to the national average of US$6.8K,[144] and is considerably lower (52%) than Campinas city. Recife city's population accounted for 17.4% of the population of Pernambuco State in 2010, and 0.8% of total Brazilian population (IBGE, 2010c).

Pernambuco State, and the Recife region in particular, experienced an economic downturn in the 1980s, which was followed by recovery efforts aimed at boosting the region's economic dynamics. The main reason for the downturn was its historical economic dependence on sugar cane production. The industry dynamics changed in the late 20th century following a fall in international prices due to the entry of more sugar cane producers, which resulted in fiercer international competition (Oliveira, 2008).

Compared to Campinas, the scientific system in Recife is diminished both because the public research university does not perform at the same level in as many scientific fields as the research university in Campinas,[145] and because the Pernambuco State Research Foundation (FACEPE) budget in 2009 was estimated in US$17.2M (i.e. more than 20 times lower than the FAPESP budget) (FACEPE,

[143] Unicamp is one of the two Brazilian universities in the *Times Higher Education* ranking in 2007, and was in 177th position (São Paulo State University was ranked 175th). http://www.timeshighereducation.co.uk/hybrid.asp?typeCode=144, accessed 16 February 2011.

[144] Exchange rate is based on the Brazilian Central Bank conversion rate of R$1 = US$2.337, for 31 December 2008. Available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, accessed 16 June 2011.

[145] The scientific disparity between the two regions is shown by the Capes Foundation triennial assessment of postgraduate programmes offered by national universities, where the highest score of 7 applies to postgraduate programmes offered by the top international universities. In the period 2006-2009 Unicamp offered 66 postgraduate programmes assessed as follows: 15 programmes scored 7, 13 programmes scored 6, 25 programmes scored 5, 10 programmes scored 4, and 3 programmes scored 3. In the same period, the Federal University of Pernambuco-UFPE, the strongest research university in the state of Pernambuco, offered 62 postgraduate programmes assessed as: 2 programmes scored 6, 23 programmes scored 5, 23 programmes scored 4, and 14 programmes scored 3 (CAPES, 2010).

2006).[146] The percentage of students graduating in 2007 in the São Paulo State, 29.6% (INEP, 2009), was more than proportionate to its share of the Brazilian population, that is, 21.6% while the percentage of students graduating in 2007 in Pernambuco State, 2.6% (INEP, 2009), was less than proportionate to its share of the Brazilian population, that is, 4.6%.[147]

The rest of the chapter is organised as follows. Section 4.2 investigates the Campinas software network's infancy and evolution, highlighting the institutional setting, government incentives and ICT industry that led to Campinas becoming Brazil's leading software region. The section concludes with a profile of local software firms. Section 4.3 provides similar information for the Recife region. Section 4.4 concludes the chapter.

4.2 The Campinas Software Network

The Campinas region has a long history in ICT, going back to the mid 1960s and the foundation of the State University of Campinas (Unicamp). Unicamp is a research university that was founded to perform research linked to the needs of local industry and also to create the conditions for technological development in strategic sectors (e.g. energy and telecommunications), which at the time were controlled by large national state-owned firms (Dagnino and Velho, 1998). Unicamp was the first Brazilian university to offered degree courses in Computing Science beginning in 1969.[148] Campinas city was selected to host CPqD, the Telebrás (the Brazilian Public Telecommunications provider) research centre, in 1976 (see Chapter 3, Section 3.2.2). The establishment of CPqD had a major impact on ICT industry development in the region (see Section 4.2.1). Section 4.2.2 investigates the emergence of the software industry in the region, and Section 4.2.3 discusses the most relevant initiatives implemented to support its evolution, including the main organisations established in the region. Section 4.2.4 presents the Campinas software firms established by the end of the first decade of 2000.

[146] Exchange rate based on the Brazilian Central Bank (Banco Central do Brasil) conversion rate available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, accessed 18 November 2010.
[147] Most recent data on state populations are available only for 2010 (IBGE, 2010a).
[148] http://www.ic.unicamp.br/informacoes-gerais/o-instituto/apresentacao?set_language=pt-br, accessed 6 January 2010.

4.2.1 The Campinas ICT network's infancy

The emergence of the Campinas ICT network was promoted by state and national level government science and technology policies. State level interventions include foundation of Unicamp by the São Paulo state government in 1966 to provide a research university that offered Computing Science and Engineering degrees among others. The creation of Unicamp is related to technology policies aimed at supporting the emergence of public organisations to develop scientific and technological knowledge (see Mowery, 1995 and Chapter 2, Section 2.2.2 in this thesis). Unicamp's Computing Institute (IC-Unicamp) offers training at undergraduate (since 1969) and postgraduate (masters since 1977 and doctoral since 1994) levels. The School of Electrical Engineering and Computing (FEEC-Unicamp) began offering training in Computer Engineering in partnership with IC-Unicamp in 1990. These developments suggest that responsibility for the supply of knowledge for the ICT industry has assumed at the local level. However, whether local firms benefit from the knowledge produced through the employment of Unicamp graduates or formal collaborations with IC-Uunicamp and FEEC-Unicamp requires further investigation; this issue is discussed in more detail in Chapter 6 where we investigate the Campinas software network of innovators in the period 2006-2009.

Another important S&T policy implemented by the state government relates to mechanisms for funding R&D, which resulted in the creation of the São Paulo State Research Foundation (FAPESP) in 1962. FAPESP funds research conducted in Campinas and other regions in the state, on ICT related areas. Unicamp receives the second highest level of funding from FAPESP in São Paulo State.[149]

FAPESP supports S&T activities in several areas, including ICT, and its expenditure on all ICT related knowledge areas in the period 2004-2008 accounted for 4.8% of FAPESP's total budget of US1B for the period.[150] However, the funding shares for Computing Science and Computer Engineering is lower compared to the amount awarded for all ICT related knowledge areas, accounting for 1.62% of the FAPESP budget for the 2009 fiscal year.

---

[149] The share of Unicamp in FAPESP's budget for the fiscal year 2009 was 14.41%; São Paulo State University (USP), received a share of 45.71% (FAPESP, 2009).

[150] This figure is based on FAPESP (2008) and an anonymous interviewee.
Exchange rate based on the Brazilian Central Bank conversion rate of R$1 = US$2.337, for 31 December 2008. Available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, accessed 16 June 2011.

FAPESP funding channels include scholarships for undergraduate and postgraduate students, grants for academic researchers, special programmes and technology innovation grants.[151] The last is an example of a technology policy related to the 'thematic funding' discussed in Chapter 2, where thematic funding programmes are defined as 'programs that involve the predefinition of themes under which eligible candidates are invited to propose specific programs of research' (Steinmueller, 2010: 1192). FAPESP supports two thematic funding programmes for the development of new technologies for practical applications; the main beneficiary is the private sector. These programmes are the Technological Innovation in Small Businesses Programme (PIPE) created in 1997, which requires applicants to be researchers formally associated to small firms,[152] and the Partnership for Technological Innovation Programme (PITE),[153] which requires the private sector to provide matching funding of up to 50% of the total project budget. The PIPE programme is part of a technology policy directed towards the formation of networks (see Chapter 2), and applications must include actors from different organisations and sub-networks (e.g. business and skills sub-networks; see Chapter 5, Section 5.3.2.1).

The infant stage of the Campinas ICT network benefited from technology policies implemented at national government level that resulted in the creation of CPqD in 1974, and the government Renato Archer Information Technology Centre (CTI/CenPRA) in 1982. CTI/CenPRA conducts R&D for the IT industry, and employed about 280 staff in 2009. It conducts research in microelectronics, software and IT applications.[154] This complemented state government technology policy discussed above (such as the creation of Unicamp to provide high quality human resources training), through the funding of organisations to develop scientific and technological activity more generally.[155]

---

[151] http://www.FAPESP.br/en/materia/1/the-institution/FAPESP.htm; accessed 6 January 2010.
[152] PIPE (Pesquisa Inovativa em Pequenas Empresas) was modeled after the Small Business Innovation Research Programme implemented by the US government.
[153] PITE: Progama de Apoio em Parceria para a Inovavação Tecnológica.
[154] Microelectronics includes Hardware Systems Design - Design House CTI, Microsystems and Electronic Packaging, Conformity and Quality Assessment, and Displays and Surface Interaction Lab. Software includes Development Technologies, Quality and Process Improvement, and Information Security. IT applications comprise: Robotics and Computer Vision, Decision Support Technologies, and 3D Technologies.
http://www.cti.gov.br/english/index.php?option=com_content&view=frontpage&Itemid=1, accessed 8 July 2011.
[155] http://www.cpqd.com.br/2/115+historico-historico.html, accessed 13 January 2010.

CPqD historically has supported the creation of spin-off firms, which led to formal and trust-based ties with the research centre because: i) many entrepreneurs were previous employees of the centre and personal relationships were in place; and ii) CPqD was confident about the high quality of the knowledge and services produced by those firms. CPqD established ties with Unicamp through the employment of Unicamp graduates and through centre employees collaborating in teaching at Unicamp.[156] The ties between CPqD, its spin-off firms, other local firms, and Unicamp were indirectly supported by guaranteed purchases of equipment by Telebrás, and also CPqD outsourcing some of its development activities to local firms. There was an endogenous process of technology development and diffusion in the region (Garcia, 2000: 9-10), involving interaction between CPqD and local firms, which created a telecommunication industry local system of innovation (Szapiro *et al.*, 2002).

The Campinas telecommunication innovation system virtuously evolved through the interactions described above and, also, benefited from the region's good reputation for supplying high quality knowledge (Unicamp's training and research), funding (e.g. from FAPESP) and the presence of the two public ICT related research centres, CPqD and CTI/CenPRA (Szapiro, 2003; Szapiro *et al.*, 2002). This environment attracted ICT MNCs, which began to set up factories in the region in the late 1970s. They included IBM, Lucent Technologies, Motorola, Nokia, Siemens, NEC, Ericsson, Compaq and Texas Instruments (Garcia and Roselino, 2004: 181).

The region's infrastructure was important for attracting MNCs, especially the road linking the Campinas region to other country regions and the presence of an airport that allowed cargo to be transported (MNCs imported ICT components from their global suppliers).[157] According to Garcia and Roselino (2004), the infrastructure was the most relevant regional characteristic, with the local scientific and technological system playing a secondary (although important) role in attracting MNCs. This questions the effectiveness of government investment in the region to support the development of local firms and their inclusion in global markets. The foundation of

[156] According to the pilot fieldwork interview number 7 CPqD historically interacted with ICT firms and other research centres and local academia. The creation of the CPqD community corresponds to the formation of a community of common knowledge in Pavitt's (1987, Chapter 2 above) terms.

[157] Imports of telecommunication components and final products increased from US$855M in 1994 to US$3.7B in 2001 suggesting the importance of importing for the Brazilian telecommunications industry (Szapiro, 2004).

private non-profit research institutes by the MNCs, created with the specific aim to perform customised R&D for them (and benefit from the Informatics Law tax exemption – see Chapter 3), suggests that local firms were not directly related to development activities performed by MNCs. According to Stefanuto (2004: 72), the level of cooperation between both local firms and the local research community, with private non-profit organisations was poor, resulting in low diffusion of the R&D activities performed by these last organisations.

Despite the centrality of the transport infrastructure, Campinas shows evidence of Marshallian industrial districts in the meaning in Markusen (1996). Business units related to the telecommunication industry were attracted to the city (and surroundings) to benefit from its reputation, potential knowledge spill-overs, and a protected market. One of the most important advantages for the region's ICT development was the institutional setting imposed by national government which meant that local telecommunication firms and research centres benefited from a protected internal market, which continued until the early 1990s with the opening-up and liberalisation of the Brazilian economy. Economic liberalisation influenced the evolution of the local telecommunications industry, with consequences for the development of the Brazilian software industry.[158] Section 4.2.2 looks at some of the results of these changes in the Campinas ICT industry, and the emergence of the software industry in the region.

4.2.2 Evolution of the Campinas ICT network: The emergence of the software network

The Brazilian economy experienced a liberalisation process at the beginning of the 1990s after more than two decades of internal market protection related to the industrialisation by import substitution model (see Chapter 3, Section 3.2.3). The new macro-economic policy influenced the evolution of the Campinas telecommunication system of innovation, especially after the privatisation of Telebrás in 1998. The major change for the Campinas region was that CPqD became a non-profit private foundation, lost its guaranteed government procurement from

[158] The liberalisation of the Brazilian economy affected the development of other local industries (see Chapter 3).

Telebrás and had to compete in the national market with private ICT firms, which mostly were global players.[159]

These changes had consequences also for local firms involved in CPqD development activities. Once the latter's guaranteed procurement ended, its ties with local firms came under pressure.[160] Local firms also had to compete with global players and, although some firms had developed strong technological capabilities in telecommunications by the 1990s, their size (small compared to global players) made it difficult for them to compete (Garcia and Roselino, 2004). The privatization of Telebrás contributed to the weakening of the Campinas telecommunication system of innovation (Szapiro, 2003). In many cases, the technological activities performed by local firms were severely downgraded (Garcia and Roselino, 2004; Ritz, 2008). Also, MNCs high technology research was mostly conducted elsewhere (e.g. in their home countries), to achieve better use of resources and economies of scale in research and economies of central coordination. The MNCs' local market share in telecommunications equipment grew from 58.5% in 1997 to 91.3% in 2000, and CPqD's role in the local telecommunication innovation system had changed (Szapiro, 2004). The new economic context discussed above led CPqD to revise its business strategy, as noted by an interviewee:

> All of a sudden CPqD was exposed to an open and extremely competitive internal market, we [CPqD] got 'exposed' to external competitors and had to learn very quickly how to be more competitive, and also how to sell our products. There was not enough time for us [CPqD] to adjust to the new reality; there was no time for a learning process. This was one of the reasons why CPqD decided to produce software and not only telecom software. The other reason was that we [CPqD] assessed that Brazil had lost the opportunity to compete internationally in the hardware industry, so we [CPqD] decided to concentrate our activities in software development (…) Also, we [CPqD] thought that the Brazilian software industry was lucky in a way, because when we [CPqD] decided to compete in software, the software industry had passed its early stage of the industry cycle, when the costs of production are known to be higher. (Pilot fieldwork interview)

CPqD began to invest in software development, an activity that previously was marginal in the centre's technological activities despite the centre's accumulated expertise in the development of embedded software related to the production of telecommunications hardware. The decision to invest in software was based on three

---

[159] Campinas pilot fieldwork number 7.

[160] This relates to the discussion in Chapter 2, Section 2.2.2 on the role of state intervention through incentives to create and maintain ties.

reasons: i) the centre was not capable (at least in the short term) to cope financially with the adjustments required to compete in the telecommunication hardware market; ii) the centre had accumulated knowledge and technological expertise in software whilst developing hardware for telecommunications; and iii) the Brazilian hardware industry had missed its chance to join the international hardware market, but the software industry was still relatively young making entry into the international software market more feasible.[161] Since the late 1990s CPqD has been developing and commercialising software and has become a major player not only in the Campinas region, but also nationally.[162]

The above discussion shows that CPqD became a central ICT player in the Campinas region when ties created with local firms and the local research university were protected by the market reserve policy. When the macro-economic environment changed and the research centre began to focus on software development, the ties between CPqD and local firms changed. This is investigated in Chapter 6.

In addition to CPqD's change of technological expertise to software development, in 1993, a major institutional change was implemented in the country aimed at developing the Brazilian software industry, the Softex Programme (see Chapter 3). The Softex Programme chose Campinas to host a Softex Nucleus, which provided major support of the local software industry. The Campinas Softex Nucleus was set up to coordinate the local software network and support local software firms' innovation and development. Initially, the Campinas Softex Nucleus was based on the Unicamp Campus, located next to the IC-Unicamp building. It was hoped that the geographical proximity between academics and entrepreneurs would foster interactions.[163] For Unicamp, liberalisation of the Brazilian economy, which corresponded to the privatisation of state-owned firms in strategic sectors, changed the university's institutional conditions with regard to the creation of new knowledge

[161] Campinas pilot fieldwork number 7. According to the interviewee, Brazil decided to enter in the software industry market when entry costs were lower than at later stages in the product life cycle.
[162] Note that although the changes in the Campinas ICT industry were not the result of technology policies, the implementation of new macroeconomic policies by national government shifted national telecommunication industrial technological development. This is discussed in Mowery (1995) in relation to the practice of technology policy. Mowery (1995: 514) states that most government policies influence nation technological and industrial development, but that only those policies that are 'intended' to 'influence the decisions of firms to develop, commercialize or adopt new technologies' are technology policies.
[163] It was claimed that geographical proximity would support the benefits of cognitive proximity in the understanding in Asheim and Gertler (2004, as discussed in Section 2.2.1, Chapter 2 above).

and its interaction with the private sector. There were few opportunities for long-term research contracts with state-owned firms, and mostly short-term research contracts with the private sector aimed at solving practical problems (Dagnino and Velho, 1998).

In 2009 (during the data collection period for this thesis) the Softex Campinas and Softex National Office were based in a separate building, located outside the Unicamp Campus. However, access was through Unicamp's gates. According to interviewees, being geographically close to Unicamp was an intangible asset of the Nucleus.[164] Between 2000 and 2010 the Campinas Softex Nucleus increased its efforts to support local firms in an effort to improve its reputation in the community as an organisation that was capable and had the expertise to support local firms. The interview extracts in the early years of 2000s demonstrate problems faced by Softex Campinas in this period:

> The Softex staff do not know what is going on in the local firms. They [Softex staff] do not how much is their [local firms] turn over, what they [local firms] do, which kind of activity they [local firms] are developing. (Campinas pilot fieldwork interview number 5)

And,

> The big problem with Softex is that the organisation receives funding from the government, so they [Softex] consider the government their main client, and not the firms. They [Softex] are very interested in lobbying, because all of Softex products are directed to fulfil policy interests with the government, they [Softex] want to sell their projects to the government with the intention of getting more funding (…) the firms that succeeded did it on their own, through autonomous trajectories. (Campinas pilot fieldwork interview number 6)

The issues highlighted by interviewees were overcome at least in part by Softex Campinas offering support to local firms, for example by extending its incubator programme, supporting and subsidising certification of local firms in software improvement (MPS.br, see Chapter 3) and facilitating the creation of a consortium of local firms. Section 4.2.3 examines some of these issues.

[164] Campinas interviews number 7, 20, 22, 25, 33, 35, 42 and 44.

4.2.3 Initiatives to support Campinas regional development and the local software industry

In addition to the Softex Programme, the Campinas local council acknowledged the importance of innovation for the development of local firms. In 1991 the council created the Company for the Development of Campinas High-Technology Park (Ciatec), a division of the council that managed two High-Technology Parks (I and II) based in Campinas which hosted high-technology firms. These parks in practice function as a set of office condominiums for firms, and Ciatec is not active in coordinating dyadic interaction among the firms in the parks.[165] In 1996 Ciatec created an incubator programme to support high-technology based firms, 'mirroring the experiences of Europe and the USA' (Campinas fieldwork organisational interview). The incubator is based at Ciatec's central office (which is outside the technology parks) and supports software start-ups, although in most cases it refers these start-ups to the Softex Campinas incubator, one of two other local incubators (the second being Incamp).

The Softex Incubator was inaugurated in Campinas in 1995, and supports only software start-ups. The incubator offers subsidised office facilities and infrastructure, which includes telephone, internet connection, reception services, cleaning, parking and security.[166] Incubator firms also have access (at subsidised cost) to workshops organised by the Softex Campinas and can obtain consultancy services. The most common entrepreneur profile in the incubator is IC-Unicamp graduate students who often have little (if any) university training in entrepreneurship. Start-ups entrepreneurs normally struggle with business plans, and the business consultancy focuses on remedying this lack of knowledge.[167] As noted by an interviewee:

> these guys [entrepreneurs] leave university thinking that they have a brilliant idea, and they may have a technological insight, but they have no idea on how to put their ideas into practice, they have no idea of what a business plan comprises of, they do not know who their consumers are. So the [Softex Incubator] makes the bridge between the 'good idea' and how to make it feasible. (Campinas fieldwork organisational interview)

In the 2000s, innovation became an increasingly important institutional issue in Campinas. In 2001 Unicamp created its own incubator, Incamp, which is located on

[165] Campinas interview number 17.
[166] Campinas interviews number 7 and 20.
[167] Campinas interviews number 12, 20, 22,.35 and 44.

Unicamp's campus and hosts high-technology start-ups, including those involved in software entrepreneurship (in most cases related to hardware development; an interviewee told us: 'we are particularly interested if the start-up produces embedded software', Campinas fieldwork organisational interview). However, as already noted, there are very few software start-ups in Incamp because most are referred to the Softex Campinas Incubator.[168] Like the other two incubators in the region (Ciatec and Softex Campinas), Incamp offers start-ups subsidised office facilities and infrastructure as well as business related consultancy. Also, and perhaps more important, there are indications that Incamp incubator firms have a good reputation among customers in terms of reliability and easier access to Unicamp faculty members.[169] IC-Unicamp historically was known for being conservative in its creation of formal ties with private industry; being based at Incamp is an asset for the incubated firms because Incamp acts as an informal broker between the firms and Unicamp's faculty members.[170]

In 2003, Unicamp founded the Unicamp Innovation Agency (Inova), which was an acknowledgement on the part of the university of the importance of innovation for the economy. Inova incorporated Incamp in 2009, based at the Agency's facilities under its administration. Inova is responsible for several related activities; i) it serves as Unicamp's intellectual property rights (IPR) and technology transfer office to handle the knowledge produced by Unicamp; ii) it provides training in strategy and management for the Technological Innovation Nucleus (NIT) established in other technological and scientific institutions (e.g. in other universities); and iii) it promotes and coordinates Unicamp's external relationships.[171] In relation to software, Inova manages two specific initiatives.

In the early 2000s, Inova set up InovaSoft, a centre to support innovation in software through interactions among academia, and the private and public sectors. Private firms' proposals to InovaSoft must include at least one faculty member from Unicamp and provide scholarships for Unicamp students. Although initially there were no facilities at Unicamp for these granted firms, Inova renovated an old

---

[168] Campinas fieldwork incubator interview.

[169] Firms 6 and 18 mentioned that a Unicamp address on their business cards gave a good impression to prospective customers.

[170] Campinas interviews number 3, 14, 21 and 24.

[171] http://www.inova.unicamp.br/paginas/visualiza_conteudo.php?conteudo=2, accessed 19 November 2010.

Unicamp building and in June 2009 this building housed four software firms (two MNCs and two local firms). At the time of the data collection this initiative was very recent; thus, consistent results with regard to the success or failure of the initiative could not be drawn.[172]

Inova also supports ‘Unicamp Ventures’, an informal and virtual network created in 2006. Eligible affiliates of Unicamp Ventures must have had a formal link with Unicamp, through employment, study or through Incamp. The network aims to promote virtual interaction among associated firms, to support learning-by-interacting among its associates in relation to a range of issues including venture capital, public grant proposals and interactions with university.[173] In June 2009 about 70% of Unicamp Ventures firms were IT related, and entrepreneurs’ former linkages with Unicamp related mostly to IC-Unicamp.[174] Unicamp Ventures is an informal network built on the common experience of network members (Powell and Grodal, 2005), and, according to interviewees, has become an important intangible regional asset.[175] According to interviewees, Campinas local entrepreneurs feel they can rely on one another and share business experiences and activities, which requires a level of trust supported by a common understanding and feeling of belonging to a community in which collective identity plays a crucial role.

Another example of Unicamp’s indirect but strong influence on the community of local ICT firms is the ActMinds export consortium. The consortium was initially set up in 2004 by 10 ICT firms (9 from Campinas). The consortium is managed by Softex Campinas and co-financed by the Brazilian Trade and Investment Promotion Agency (APEX). An interesting feature of ActMinds is that most of its entrepreneurs previously studied at IC-Unicamp, which according to an interviewee is one of the main reasons for its success:

> the ‘embryo’ of ActMinds holds to friendship among the entrepreneurs. Many have studied at IC-Unicamp, they shared flats, or studied together. This became very important, because they feel that can trust each other, are part of the same community. (Campinas fieldwork organisational interview)

---

[172] Campinas fieldwork organisational interview.
[173] http://www.inova.unicamp.br/paginas/visualiza_conteudo.php?conteudo=131, accessed 15 January 2010.
[174] Source: confidential list provided by Inova during data collection.
[175] Campinas fieldwork interviews 11, 36 and 48.

This opinion is confirmed in Marinho and Simis (2007); their findings show that ActMinds entrepreneurs felt that were all part of the same community, which provided the required level of trust to initiate and implement the project. In relation to trust issues, the ActMinds executive-coordinator is a key person who facilitated the discussions pre-consortium formation and has contributed to its evolution. This executive-coordinator has a history of professional experience with the software industry; he has worked at the Softex National Office, was a local software entrepreneur and is a graduate of IC-Unicamp. However, all the firms involved in the consortium were positive and motivated (Marinho and Simis, 2007). Another benefit is the geographical proximity of firms, which confirms the claims that this leads to positive collective outcomes (as discussed by Cooke and de Laurentis, 2010).

Although Unicamp has had a positive influence on the establishment of local software firms (e.g., through provision of training in Computing Science) and the interactions among local software entrepreneurs (through Unicamp Ventures and ActMinds), formal collaborations between Unicamp and local software firms has been less successful (see Chapter 6). This is because: i) the local industry has not engaged with scientific problems at the knowledge frontier (MIT-Softex, 2002; Roselino, 2006); ii) Unicamp historically benefited from public funding; for instance, Unicamp holds a significant share of FAPESP's budget for research (FAPESP, 2009); and iii) Unicamp faculty members are assessed by CAPES based on numbers of publications in top indexed journals (which requires that academics perform high level research usually not related to the resolution of technological level practical problems).

This discussion illustrates the implementation of initiatives to support the Campinas software industry at different levels (mainly state and federal) and the different organisations involved. Although these initiatives were not coordinated centrally but rather were a collection of individual initiatives, they fostered the creation of local software firms (see Section 4.2.4).

4.2.4 The Campinas software firms and the main network actors

According to National Classification of Economic Activities (CNAE), which is coordinated by the National Classification Commission (CONCLA, IBGE), in 2009 there were 104 software firms based in Campinas. Table 4.1 summarises the number of firms and employees by industry category in CNAE.[176]

Table 4.1 Campinas software firms by CNAE Classification (2009)

Software related IT activities	No. of firms	(%)	No. of employees	(%)	Average no. of employees
Customised computer programme development	47	45.2	478	32.4	10
Development and licensing of customised computer	8	7.7	108	7.3	14
Development and licensing of non-customised computer	30	28.8	589	39.9	20
Consultancy in IT	19	18.3	301	20.4	16
Total	104	100	1476	100	14.2

Source: CNAE/ Comissão Nacional de Classificação, IBGE (2009).

Table 4.1 shows that most Campinas software firms are involved in customised software and are micro or small firms; this is confirmed by the data collected during fieldwork (see Chapter 6). This is a common characteristic of the Brazilian software industry (see Duarte, 2003; Oliveira, 2008; Roselino, 2006; Britto and Stallivieri, 2010; MIT-Softex, 2002; Veloso *et al.*, 2003).

Table 4.2 shows the large number of other network actors operating in the region related to the development of the Campinas local software industry.

[176] Box A1 (in the Appendix) provides a full description of the activities included in each CNAE category.

Table 4.2 Campinas network actors

Actor	Year of Foundation	Main activities
APEX-Brasil	1997	Promotion of Brazilian exports
Campinas City Council	n.a.	Fiscal policies
Ciatec	1991	Manage the two Campinas High-Technology Parks
Ciatec Incubator	1996	Incubation programme
CNPq	1951	Brazilian Research Council
CPqD	1976	R&D centre
Criatec-Fund	2007	Venture capital fund/ BNDES and private sector
CTI/CenPRA	1982	R&D centre
FAPESP	1962	State level research foundation
FINEP	1967	Brazilian Innovation Agency
FITec-Campinas	2002	R&D centre (founded by MNC)
Incamp	2001	Incubation programme
Inova Soft	2003	Inova Centre for Information Technology
Inova Unicamp	2003	Unicamp Innovation Agency
Instituto Eldorado	1997	R&D centre (founded by MNC)
Prosoft-BNDES	1999	BNDES programme for software
PUC-CAMP	n.a.	Training in IT undergraduate.
Sebrae-SP	1972	Support for micro and small entrepreneurships
Secretary for Development/SP	1965	Promote sustainable economic growth and technological innovation in the São Paulo State.
SIDI		R&D centre (founded by MNC)
Softex Campinas	1993	Fostering and support local software industry.
Softex Campinas Incubator	1995	Incubator programme: software only
Unicamp-FEEC	1967	Training in IT undergraduate, Master's, professional Master's, Doctorate and Post-Doctorate
Unicamp-IC	1969	Training in IT undergraduate, Master's, professional Master's, Doctorate and Post-Doctorate
Venturus	1995	R&D centre (founded by MNC)

Legend:
n.a. = not available
Source: own elaboration from organisations' websites and literature review.

4.2.5 Summary

This section discussed the emergence and recent development of the Campinas software network. The region received considerable investment related to the IT industry from the private (e.g. establishment of private non-profit R&D centres) and public (e.g. the investment of FAPESP by the state government, and CPqD and CTI/CenPRA by the federal government) sectors. The Campinas software industry has built an excellent reputation in the national market, which influenced its development by attracting well established firms and organisations. The region has benefited from its long ICT history, which has supported a virtuous growth cycle for local software firms.

4.3 The Recife Software Network History

The software industry is relatively recent in the Recife region. It began in the 1980s and benefited from the establishment of the Softex Agent in 1992, the creation of the private non-profit Recife Center for Advanced Studies and Systems (CESAR) in 1996 and from the Pernambuco state government intervention that resulted in the creation of Porto Digital in 2000. This section discusses the infancy of the Recife software network, its evolution and the profiles of the software firms established in the region in 2009. Sections 4.3.1 and Section 4.3.2 examine the promotion of the IT industry and the emergence of the regional software network. Section 4.3.3 addresses recent initiatives to support the development of the Recife software network, including the organisations in the region; Section 4.3.4 introduces the firms in the region.

4.3.1 The infancy of the Recife ICT network

The Recife IT industry began in the 1960s when IBM established an IT centre in Recife that employed personnel skilled in computing and engaged mainly with the regional banking system, in particular the Banco Nacional do Norte (Banorte), a private bank that was the first banking organisation to introduce intranet to support banking operations in Brazil, using IBM equipment.[177] Another organisation that played an important role in the development of IT activities in the region is Bom Preço, a large supermarket chain, initially owned by a north-eastern Brazilian business group, which also employed IT professionals.

In Chapter 3 we show that until the early 1990s it was common for large organisations of develop IT related activities internally. Banorte and Bom Preço played a major role in IT industry development in Recife.[178] Both organisations were involved in IT development in Recife and provided sophisticated IT services and

---

[177] Recife interview number 21 and http://www.elogica.com/main/portal/clipping/jornalCommercio/2007-09-27jc.html, accessed 10 January 2010.

[178] Recife interviews number 18 and 21.

products. In 1987, Bom Preço was the first supermarket in Brazil to offer automated Points of Sale and use optical scanners.[179] By the mid-1980s, Banorte and Bom Preço employed together about 600 highly skilled IT personnel and the region's IT industry was prospering.[180] In 1974 Pernambuco Federal University (UFPE) began to offer a degree in computing science from the Physics Institute; in 2009 training in computing science is offered by the Informatics Centre (Cin-UFPE).[181] The offer of a Computing Science degree by a federal university demonstrates the Brazilian national government's support in the form of funding the provision of well qualified IT human resources for the region. The role of Cin-UFPE has been crucial for the Recife software network.

In 1986, Cin-UFPE decided to modify its undergraduate Computing Science degree syllabus because it realised that students needed some training in entrepreneurship in order to foster the creation of local IT firms (Oliveira, 2008).[182] The new syllabus differed in two ways: i) it included issues related to market demand; and ii) it included academic training in entrepreneurship. It was believed that this would help to redress the imbalance between supply and demand of specialised knowledge, a common dysfunction in the Brazilian system of innovation (see Chapter 3). The decision to rewrite the syllabus coincided with an internal assessment that the department was lagging scientifically, behind national and international computing science centres:

> when [one of the faculty members] came back from [his] PhD in England [by the mid 1980s], [he] realised how far behind [the department] was in terms of equipment and technology. To give an example, the equipment we [the department] were using in the labs here [Cin-UFPE] had been replaced in the lab [he] worked for [his] PhD in England for more than ten years. So [he] thought that something had to be done about it, otherwise [the department] would be a peripheral university centre forever, it was an 'all or nothing' situation. So [the department] decided to change [its] undergraduate syllabus and send its [Cin-UFPE] faculty to be trained abroad for Masters and PhD degrees. We [Cin-UFPE] estimated that in 15 years the centre would be internationally recognised as an important research university department, which was achieved much earlier than that. (Recife fieldwork university interview)

179 http://www.comunique-se.com.br/produtos/saladeimprensa/walmart1/show.asp?_mat=21755&_ed=696&_tar=S&_sec=ii4, accessed 10 January 2010.
180 Recife interviews number 2, 12, 13 and 21.
181 The name of the centre has changed several times; here we refer to it as Cin-UFPE throughout. See Oliveira (2008) for a chronology of the changes.
182 Recife interviews number 10, 12 and 25.

Although Cin-UFPE is part of the federal university system, the above interview extract suggests that there was a bottom-up initiative promoted by the local research university to foster a change in the region's peripheral scientific development in computing science (in the form specifically of policies to support the emergence or improvement of institutions developing any kind of scientific or technological activities – see Chapter 2, Section 2.2.2).

In addition to the changes in Cin-UFPE, in 1989 an important policy was implemented at state level to create the Pernambuco State Research Foundation (FACEPE). FACEPE's main mission in 2009 was to foster scientific and technological development in Pernambuco State by providing support for science, technology and innovation.[183] FACEPE offers scholarships for higher education training at undergraduate and postgraduate levels, and awards grants for research projects by university researchers as well as research performed in private-sector firms.[184]

As a result of Cin-UFPE's efforts, by the mid 1990's the majority of Cin-UFPE faculty members had been trained abroad to doctorate level, which improved the institution's scientific reputation.[185] Graduates began to enter the national labour market.[186] Cin-UFPE graduates were attracted to other regions (especially the Southeast region) because of the lack of IT positions locally. In the 1990s Banorte went bankrupt and Bom Preço was sold to an international food chain.[187] This greatly reduced the opportunities in Recife and most IT activities were transferred to the Southeast Brazilian region or went abroad (as in the case of Bom Preço), or ceased (as in the case of Banorte). Highly trained Cin-UFPE graduates had no

[183] http://www.facepe.br/modules.php?name=Content&pa=showpage&pid=1, last accessed 19 March 2011.

[184] FACEPE played a very important role for the evolution of the Recife software network, as we will discuss in Section 4.3.3 below.

[185] Recife interviews numbers 12 and 25. In addition, Cin-UFPE was assessed by CAPES postgraduate degree assessment exercise for the 3 years 2007-2009, and received grade 6 (this was matched by only two other computing sciences departments in Brazil, out of 53). Grade 6 is one below the highest level of grade 7 which is equivalent to international standards (only 2 other Brazilian computing sciences departments were assessed as 7) (CAPES, 2010).

[186] According to this interviewee Cin-UFPE invested in the Java language from the start although other Brazilian university centres did not. As a result, when the private market needed skilled java trained human resources, Cin-UFPE's graduates were well positioned in the labour market. Recife fieldwork university interview and Oliveira (2008: 146).

[187] In 2009 the chain was owned by Wal-Mart.

opportunities locally to use and develop their skills, and looked for job opportunities outside Recife.[188]

In addition, most large IT firms (including MNCs) were in the Southeast region. Recife IT trained human resources were attracted by the higher wages and good working conditions and more advanced technological activities than were available in Recife.[189] The migration of Cin-UFPE graduates to other regions represented a brain drain for Recife and Pernambuco State:

> what happened was that the labour force trained by Cin-UFPE was extremely skilled in IT and the local demand for IT development was very simple. Then what could students who were graduating from Cin-UFPE do? The only option was to leave Recife, and so they did. In 1993, Microsoft created a temporary bureau at Cin-UFPE to hire recent graduate students; it represented a clear brain drain for the region. (Recife fieldwork interview number 21)

Another local initiative to create a local software industry in Recife was the Softex Programme implemented by the Brazilian Federal government (see Chapter 3), and the establishment of the Recife Softex Nucleus (in 2009 Softex-Recife). The Softex programme aimed to support software exporting firms and was established at the time when Banorte and Bom Preço employees were made redundant. The Softex Recife programme supported the creation of some new firms set up by former Banorte and Bom Preço employees and the re-establishment of the Recife software industry. The importance of SoftexRecife is summarised by an interviewee as follows:

> Softex-Recife provided the minimal institutional infrastructure to firms that were founded by Banorte's former employees. When Softex-Recife was established there were 16 IT firms in Recife and among those 12 were founded by Banorte former employees. (Recife fieldwork organisational interview)

The evolution of the Recife software network experienced a major shift in the mid 1990s with the creation of the Recife Center for Advanced Studies and Systems (CESAR), a private non-profit innovation centre that performs IT research and development (see Section 4.3.2).

[188] Recife fieldwork interviews numbers 1, 10, 12, 13, 21 and 25.
[189] Recife interviews numbers 9, 10, 12, 13, 21 and 32.

4.3.2 Evolution of the Recife ICT network: Emergence of the software network

The migration of highly skilled IT human resources from Recife to other regions was seen as a setback in the efforts of Cin-UFPE to promote the local software network by increasing the supply of highly skilled IT personnel. Also, entrepreneurship among Cin-UFPE graduates was not as high as expected. These phenomena triggered the creation of CESAR in 1996 by a group of Cin-UFPE faculty members. In its first years, CESAR's headquarters were located next to Cin-UFPE (on the university campus).

CESAR was founded to offer high quality employment for Cin-UFPE graduates. A unique characteristic of CESAR was its foundation by a university group; other R&D organisations founded in Brazil (and in the region at a later date) were private sector initiatives (see Chapter 3). CESAR provided a strong link between Cin-UFPE and the private sector, as noted by an interviewee:

> the group within Cin-UFPE that believed in a closer relationship with the private sector was the leading group in the organisation at that time, and because of this leadership the group managed to break the university [UFPE] institutional ties, which were quite weak (…) The university had no idea what we [Cin-UFPE] were doing when we founded CESAR, and when the university administration realised that something was going on, we [Cin-UFPE] were already concluding the construction of the building that hosted CESAR, and there was no way back by then. Moreover, there was nobody in UFPE that could assess what we [Cin-UFPE] were doing. Nobody in UFPE understood innovation at that time, so they just let us to continue with the initiative. Somehow they [UFPE central administration] trusted that we [Cin-UFPE] were doing the right thing. And that would never happen, for example, at Unicamp. For sure Unicamp would had had formed committee to discuss the relevance of an initiative like CESAR's, and they [committee] would take a century to agree on a decision. Unicamp's institutional framework is far more 'rigid' than in UFPE, and the experience we lived in creating CESAR is unthinkable in their [Unicamp] context. (Recife fieldwork university interview)

CESAR has become a leading Brazilian IT R&D centre.[190] The centre has grown considerably and in 2008 employed 672 staff, 69% of whom were engaged in IT development activities (Ritz, 2008: 126). CESAR's portfolio of initiatives has increased to support consolidation of the Recife software industry.[191] For instance, the centre offers an incubator programme and has an education division,

[190] In 2004 CESAR won the Finep Prize in the best Innovation Institution award category. http://www2.finep.gov.br/premio/index.php?pg=historico, accessed 19 March 2011. In 2010 CESAR won the Finep Prize in the best Science and Technology Institute award category. http://www.cesar.org.br/site/c-e-s-a-r-vence-premio-finep/, accessed 19 March 2011.

[191] Recife fieldwork interview number 12.

CESAR.edu, which offers a professional Masters Degree in Software Engineering, and continuing education courses in IT related areas. CESAR.edu was set up initially to supply the local skilled labour force and was a kind of bottom-up arrangement to support organisations that were developing any kind of scientific or technological activities (see Chapter 2, Section 2.2.2). CESAR has a division that supports local investment through partnerships, CESAR.par, mostly with former and current incubator firms.

The establishment of the Softex-Recife office represented a major step towards the creation of a local software industry in Recife, and occurred almost simultaneously with the changes at Cin-UFPE and the creation of CESAR. However, the most important recent investment to consolidate the local industry was the creation of Porto Digital by the State Government of Pernambuco.

The Porto Digital initiative was financed by the Pernambuco Secretary of Science and Technology and the Environment (SECTMA) in 2000 and implemented by the Porto Digital Management Unit (NGPD) in the same year. Porto Digital is a restricted geographic area on Recife Island, part of Recife city, which hosts software firms and other IT related organisations (see Figure 4.1).

Figure 4.1 Recife Island

Note: Porto Digital occupies 60% of Recife Island, the remaining 40% of the Island area belongs to the Brazilian Marine Force.
Source: http://recifeguide.files.wordpress.com/2008/12/recife-antigo-aerial-view.jpg, accessed 9 March 2010.

The choice of the Recife Island to host Porto Digital was related in part to the economic decline in Pernambuco State, which for some 400 years had relied on sugar cane production to sustain its economic development (Oliveira, 2008: 69). At the end of the 1990s, SECTMA considered that Pernambuco State needed to formulate and implement a new technology policy that would support the economic development of different regions within the state in the following decades.

The policy focused on the formation of regional clusters within the state, with the choice of industry to be supported by each cluster based on the advantages of each region (SECTMA, 2006: 82-83).[192] By the late 1990s Recife Island Port had lost its economic vitality, which had been based on exporting locally produced sugar cane. It had been overtaken by the new Suape Port Complex.[193] SECTMA did not see that the Recife Island port was viable. An IT cluster, a knowledge intensive industry, would not need the services of a port, and it was believed, would restore the Island's economic dynamism (da Silva, 2008: 3).[194] Porto Digital saw a concentrated geographic area as an asset and believed it would foster and support networking among software firms and with other IT organisations:

> delimiting the territory is one of the reasons that explain the success of the Porto Digital strategy (…) we [policy makers] followed a local system of innovation approach, we [policy makers] knew how important the interaction would be for the development of the local industry, we wanted people to be in contact with one another, sharing their experiences, getting to know one another, to build trust between firms. The location is extremely important for the governance of the network. Today [April 2009] firms' entrepreneurs and employees bump into one another because the geographical area is very delimited, they meet by chance at lunch time, they all go to lunch at 12pm at the Paço Alfângeda [local shopping centre], and lots of experience are informally shared during these occasions. And if there is disagreement between these people, lots of it gets cleared during informal gatherings. (Recife fieldwork organisational interview).

The technology policy implemented by SECTMA through the Porto Digital project had government level involvement and also input from Cin-UFPE, Softex-Recife, the Brazilian Association for Information Technology Firms Pernmabuco Office

---

[192] Recife interviews number 9.

[193] Suape Port is also in Pernambuco State, but in a different region. Suape has been the main port in the Northeast region since the late 1990s. http://www.suape.pe.gov.br/institutional/historic.php, accessed 19 March 2011.

[194] Recife 2000 HDI was 0.78, the 28th in Brazil (the study measured 33 cities/regions, therefore Recife presented a score in the lower end of the sample) http://www.pnud.org.br/atlas/ranking/RM_Ranking.doc. According to Waiselfisz (2008) Recife was in 2006 the 3rd Brazilian city in the total numbers of homicides, which ranks the city as one of the most violent capitals in Brazil.

(Assespro) and CESAR.[195] According to interviewees, this added to the success of the project, because different sectors of society were cooperating in project implementation and development, allowing different demands to be accommodated.[196] There have been four stages in the development of Porto Digital (da Silva, 2008; Marinho, 2008) (see Section 4.3.3).

4.3.3 Initiatives to support Recife regional development and the local software industry

The first stage in Porto Digital's development was its formal creation and choice of governance model, described by da Silva (2008) as the 'Existence Stage'.[197] SECTMA wanted political independence for the Porto Digital project and a new governance model organised by a new management unit, NGPD, a Social Organisation.[198] NGPD was given responsibility for managing the public financial resources directed to Porto Digital development, formulating and implementing future policies for the local software industry, and supervising governance of the network.[199] SECTMA delegated its responsibilities as policy formulator to NGPD, but still provided the majority of the financial resources for Porto Digital development through a management contract with NGPD.

In 2000, SECTMA committed about US$18M to Porto Digital, to be managed by NGPD.[200] This sum included a building on Recife Island whose space could be leased by software firms, which was suppose to provide NGPD with financial independence in the future. The management contract held by NGPD stated that SECTMA would continue to provide financial support to NGPD, however, no figures were agreed at the outset and this issue later became contentious.

---

[195] Recife interviews number 9, 10, 12, 13, 21, 25 and 32.

[196] According to the interviewees, the successful engagement of the state government, academia (Cin-UFPE) and industry (Softex-Recife and Assespro-PE) related to trust based, long term personal relationships between the representatives of those institutions. Recife interviews number 9 and 10.

[197] Recife fieldwork organisational interview.

[198] The new governance model was supposed to avoid the problems common in Brazilian government policy programmes of discontinuity due to political changes, as discussed by Velho and Saenz (2002). The problem of local policy programme discontinuity was mentioned by several interviewees. Recife interviews numbers 1, 3, 4, 8, 9, 10, 12, 18, 21, 25, 26, and 28.

[199] NGPD Council has 17 seats to allow representation from different parts of society, including the private sector, local and state government, and the universities: '37% government representatives, 21% from the productive sector, 11% from universities, 16% from non-governmental organisations, and 16% from other groups of society', www.portodigital.org, accessed 2 December 2009.

[200] Exchange rate uses the Brazilian Central Bank (Banco Central do Brasil) conversion rate available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, accessed 18 November 2010.

During this first stage, FACEPE played an important role by providing scholarships for human resources training and grants for training in IT related subjects (FACEPE, 2006). The Human Capital Fund (FCH) co-financed the development of ICT professionals for companies based in Porto Digital (da Silva, 2008: 9-10).[201] In addition, there were several government incentives to attract software firms to Recife Island. These included: i) assistance over land use conditions imposed by the Recife City Council administration with regard to historic buildings restoration; ii) reduction of up to 60% of Service Taxation imposed by Recife City Council (from the city council administration); iii) reduction from 17% to 1% in Taxation on Goods and Services to software firms (from the State of Pernambuco administration); and iv) a Loan Guarantee Fund: the Guarantee Fund for Software Companies in Pernambuco (FAESPE) which provided funds to guarantee loans to ICT companies from public banks (State Act No 11.634, 1999 and amended by Act 11.732, 1999) (da Silva, 2008). The range of incentives and the diversity of actors indicate there was coordination at different government levels to support the Porto Digital project.

In 2002, that is, during Porto Digital's first stage, CESAR moved from the UFPE Campus to Porto Digital, which represented a major positive shift for the network.[202] As already discussed, CESAR has become one of the leading IT research organisations in Brazil and became the anchor for the network. The Centre brings reputation to the region, and local firms benefit from being part of its network.

The second stage of Porto Digital started in 2003; the aim was to promote the region and consolidate the 'brand' (Marinho, 2008).[203] In this stage, NGPD appointed a new director-president (the second since its foundation) whose strong experience in the private sector made him extremely suitable to manage this new phase in Porto Digital.[204] One of the objectives was to foster interaction and collaboration among firms and other institutions in Porto Digital (da Silva, 2008: 6).

---

[201] FACEPE's investments are discussed in more detail below.

[202] The original Porto Digital project aimed to bring Cin-UFPE to Recife Island, so that academic sector would be geographically close to software firms. However, there was lack of agreement among Cin-UFPE faculty members to Cin-UFPE's being based elsewhere than on UFPE campus. CESAR decided to move to Porto Digital. Recife interviews numbers 9, 10 and 12.

[203] Recife interviews numbers 9 and 13.

[204] The new director-president had previously been CEO of the Brazilian subsidiary of a multinational mobile network firm.

FACEPE continued to play a significant role in supporting Porto Digital's development, through scholarships and 'other funding channels'.[205] FACEPE increased its investment in science, technology, engineering and mathematics (STEM) related subjects using Pernambuco State Treasury resources. For instance, 'other funding channels' (than scholarships) increased fivefold in 2000 and 2002, making them six times higher than investments in Human and Social Sciences (FACEPE, 2006).[206] As mentioned above, most of FACEPE's investments were related to Human Capital Fund projects, set up by the State Government Executive Division to support the training of human resources in IT, especially in management, development, and product and process operations (FACEPE, 2006: 11). With regard to FACEPE's investments through scholarships, there was a steady increase in the financing of STEM subjects, which resulted in a better balance with other knowledge areas (FACEPE, 2006).

During this stage, government procurement played an important role in the development of local firms. According to Almeida (2008: 49), from 2003, the state government started to procure from local software firms, which changed the pattern, of software provision based on firms in other regions.

The third stage of Porto Digital started in 2006, and was aimed at strengthening Porto Digital software firms' competitiveness (Marinho, 2008).[207] The major change during this stage was the considerable decrease in SECTMA's financial support for Porto Digital. This required a new strategic plan for Porto Digital development,[208] which was designed by a local consultancy firm (WIT, 2005).[209] The plan comprised eight strategies and 86 goals. Table 4.3 presents the eight strategies, a summary of the actions and means to achieve the 86 goals.

---

[205] 'Other funding channels' refer to: i) participation in conferences and seminar in Brazil and abroad; ii) research proposals; iii) visiting scholars; iv) scientific meetings and training; v) researcher training; and vi) technical research training. Scholarships refer to: i) technical cooperation; ii) science and technology diffusion; iii) master's and doctorate; iv) researcher and technician placements; v) academic incentives; vi) scientific projects for undergraduate students; vii) technological incentives; viii) visiting scholars; and ix) technical training (FACEPE, 2006).

[206] FACEPE stopped releasing information on its investments in 2005; there are no figures available to compare investment in STEM subjects in 2009.

[207] During this stage a third NGPD director-president was appointed. According to an interviewee, each director-president had different skills that suited the needs of each of Porto Digital's development stage. Recife fieldwork organisational interviews.

[208] Recife interviews numbers 13 and 21.

[209] These strategies were devised in consultation with experts from different areas, including firms based in Porto Digital and outside, local organisations (such as Softex-Recife, ASSESPRO, CESAR, and Sebrae), government bodies, and local universities. Non-local organisations, such as ECLAC and Softex National, were also consulted (WIT, 2006); Recife fieldwork organisational interview.

Table 4.3 Strategies for Porto Digital development from 2006 to 2009

Strategies	Actions needed	Necessary steps/means
1. Increase the number of software firms at Porto Digital	• Improve urban public services and infrastructure • More fiscal incentives for firms • Increase the offer of office spaces and other services (e.g. leisure, cultural events) • Marketing policies implementation • Creation and maintenance of knowledge basis • Conclusion of ITBC building	• Articulation with government • Articulation with non software firms that are based at Porto Digital • Articulation among software firms based at Porto Digital
2. Strengthening of local software firms	• Mobilization of private and institutional funding resources • Mobilization of human capital • Technological innovation/product improvement • Improvement of entrepreneurial management skills • Certification of firms with well reputed certification processes (e.g. CMMI) • Certification of people with specific technologies and tools • Offer of entrepreneurial support services	• Articulation with venture capital firms • Articulation with government • Articulation with major market players • Articulation with higher education and training centres • Articulation with human capital funding agencies • Articulation among software firms based at Porto Digital
3. Support new entrepreneurial investments	• Define new models of entrepreneurial investments • Implementation of new models of entrepreneurial investments	• Articulation with higher education and training centres, and with funding organisations that support new entrepreneurship (e.g. Sebrae, CNPq, ANPROTEC, FINEP, and FACEPE) • Interaction and partnership with C.E.S.A.R • Articulation with INCUBANET
4. Implementation of policies directed at socio-economic responsibility and social inclusion	• Offer of social services to local community • Promotion of policies for social inclusion • Creation of job opportunities for local population • Promotion of historical sites restoration and preservation	• Articulation with local residents association, Non-governmental organisations, public institutions and firms based at Porto Digital

Legend: n.a.= not applicable
Note: the 86 goals were not displayed in this table.
Source: own elaboration based on WIT (2006).

Table 4.3 Strategies for Porto Digital development from 2006 to 2009 (continuation)

Strategies	Actions needed	Necessary steps/means
5. Conquer credibility (local and no local/ Porto Digital 'brand' strengthening)	• Policy implementation for strengthening the Porto Digital brand with local firms as well as other markets • Implementation of marketing strategy for Porto Digital focusing on critical results and factors • Promotion of Porto Digital with local social divisions so that Porto Digital becomes a local asset for the city	• Articulation with local press and specialized publication (local, national and international) • Articulation with business associations, unions, and local community • Articulation with firms based at Porto Digital and outsider firms
6. Accessing new markets	• Provision of market information and studies on the ICT value-chain (supply and demand) • Modelling strategies for competitiveness improvement in national and international markets • Implementation of marketing strategies for strengthening Porto Digital brand focusing on critical results and factors (e.g. human capital and cooperation) • Get institutional support from funding organisations that promote business (e.g. Itamaraty and SEBRAE).	• Articulation with local press and specialized publications (local, national and international)
7. Business models for local IT industry	• Mobilization of investors to make capital available to Porto Digital firms • Elaboration/implementation of strategies for merger and acquisition at Porto Digital • Improvement of governance strategies among Porto Digital software firms	n.a
8. Foster cooperation among firms	• Promotion of cooperation among local software firms aiming operational costs reduction • Formation of alliances and partnerships among firms (local and no local) so that business with bigger customers can be achieved • Dissemination of tools aiming interaction among firms, collaborators and customers (e.g. website, local newsletter, service portfolio).	• Articulation among local software firms

Legend: n.a.= not applicable
*= the 86 goals were not displayed in the table.
Source: own elaboration based on WIT (2006).

Some of the strategies in Table 4.3 suggest that NGDP needed to interact with outside organisations to get additional funding. From 2007, NGPD started to work on these strategies and the results are described in Porto Digital's fourth stage.

Table 4.4 summarises the success rate for each strategy in the period 2006-2009.

Table 4.4 Porto Digital Strategies and Goals for 2006-2009

Strategy	Number of goals*	Concluded**	Partially implemented**	Not implemented**
Strategy 1	21 goals (24.4%)	15 (71.4%)	5 (23.8%)	1 (4.8%)
Strategy 2	21 goals (24.4%)	12 (57.1%)	5 (23.8%)	4 (19.1%)
Strategy 3	3 goals (3.5%)	2 (67%)	1 (33%)	0 (0%)
Strategy 4	16 goals (18.6%)	8 (50%)	7 (43.8%)	1 (6.2%)
Strategy 5	6 goals (7%)	4 (66.6%)	1 (16.7)	1 (16.7)
Strategy 6	5 goals (5.8%)	3 (60%)	1 (20%)	1 (20%)
Strategy 7	8 goals (9.3%)	2 (25%)	2 (25%)	4 (50%)
Strategy 8	6 goals (7%)	4 (66.7%)	2 (33.3%)	0 (0%)
Total number of goals	86	50 (58.1%)	24 (27.9%)	12 (14%)

Legend:
*= Percentage refers to the total number of goals
**= Percentage refers to the total number of goals in each strategy
Strategy 1= attract more software firms to Porto Digital;
Strategy 2= strengthen local software firms;
Strategy 3= support new entrepreneurial investments;
Strategy 4= implement policies related to social inclusion;
Strategy 5= increase the network external credibility;
Strategy 6= access new markets;
Strategy 7= provide new business models for local firms;
Strategy 8= foster cooperation among firms
Source: own elaboration based in NGPD (2009b).

Although this strategic plan was designed seven years after Porto Digital had been created, Table 4.4 shows that the strategies to increase of numbers of firms in Porto Digital (strategy 1) and to strengthen them (strategy two), were prioritised by the regional software industry. This suggests that regional industrial development is a long-term and gradual process, as discussed in Chapter 2, Sections 2.2 and 2.3.

Locating Porto Digital on Recife Island was aimed to encourage collaboration among local firms and between local firms and other IT related organisations. The strategy designed to foster collaborations (strategy eight), was not a priority in terms of the number of goals, but was as successful as the more elaborate Strategies 1 and 2.

Table 4.4 shows that the goals to create a new business model for software firms based at Porto Digital (strategy seven) were the least successful (50% incomplete). These goals (new business model) included attracting investors to Porto Digital, which was implemented, and fostering alliances among Porto Digital firms to gain scale in terms of firm size, not implemented due to lack of funding (NGPD, 2009b).

During 2009 Porto Digital embarked on its fourth development stage.[210] In order to support the implementation of the strategies mentioned in Table 4.3 above, NGPD launched 16 projects and partnerships, with combined funding of US$9.1M, to be implemented in 2009-2012.[211] Table 4.5 summarises the 16 projects, which correspond to the new policy implemented by NGPD for Porto Digital development. Table 4.5 shows that NGPD funding changed. Originally, NGPD was funded mostly by SECTMA through the management contract agreement (see Section 4.3.2).[212] This funding was largely withdrawn between 2008 and 2009.[213] For instance, in Porto Digital's total funding for the period 2000 to 2010, we find that SECTMA's funding represented 37.8% of NGDP's budget between 2000 and 2006, but only 1.4% in 2007 to 2010.[214] Table 4.5 shows that of the US$9.1M funding raised by NGPD, only 11.52% was from SECTMA (NGPD, 2009a).[215]

---

[210] NGPD appointed its 4th director-president in 2007; he is still in charge in 2011. He was heavily involved in formulating the new strategies. Recife interviews numbers 9, 10, 13 and 21.

[211] Exchange rate uses the Brazilian Central Bank (Banco Central do Brasil) conversion rate available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, accessed 18 November 2010.

[212] Recife fieldwork organisational interviews; and Porto Digital (2003).

[213] Recife fieldwork organisational interviews.

[214] Personal communication with NGPD July 2011.

[215] Exchange rate uses the Brazilian Central Bank (Banco Central do Brasil) conversion rate available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, accessed 18 November 2010.

Table 4.5 Projects and partnerships for innovation at Porto Digital for the period 2009-2012

Project/ Strategy	% total budget*	Funding sources / Project Partners	Aims
1. Firms Certification / Strategy 2	3.2%	FINEP / FINEP and SECTMA	Certify local firms in methodologies and development processes
2. IT Human Capital Training / Strategy 2	5.9%	MCT and SECTMA / MCT and SECTMA	Improve local labour force in IT skills
3. Technological Vocational Centre in IT / Strategy 2 and Strategy 4	1.1%	MCT / MCT and Softex-Recife	i) Structure human capital qualification; and ii) digital literacy
4. Zero Interest Rate Programme / Strategy 2	27.2%	FINEP / FINEP, AD Diper, C.E.S.A.R and Softex-Recife	Foster the development of local innovative micro and small firms
5. 'Banda Franca' / Strategy 4	2.2%	ATI / ATI and Especial Secretary for the Youth and Employment	Free broadband access (minimum 256 kbps) in Porto Digital. Foster the development of local firms in IT.
6. Centre of Competitive Intelligence for Technological Parks / Strategy 6	8.1%	FINEP / SECTMA, FACEPE, ITEP and ParqTel	Foster local IT competitiveness through sharing strategic information in the IT industry
7. 'Porto Desembarca' / Strategy 5	2.4%	MCT and Sebrae-PE / MCT, SECTMA and Sebrae-PE	Foster the development of other regions in Pernambuco through sharing Porto Digital's knowledge and experience with other clusters
8. Porto Digital Incubator / Strategy 3	5.9%	Finep and Sebrae-PE	Foster entrepreneurship in software development
9. Management Contract with SECTMA / Strategy 1	5.3%	Finep, Sebrae-PE and SECTMA	Improve office spaces availability
10. Porto Digital Quality and Brand Programme / Strategy 6	1%	MCT / CNPq	Register Porto Digital Brand at INPI, creating a Porto Digital Label. Support local firms credibility in the market
11 Olympic Digital Games in Education / Strategy 8	27%	Pernambuco State Education Secretary / idem	Use of digital games in state schools to promote educational disciplines through games.
12. Social entrepreneurial responsibility / Strategy 4	0.7%	MCT / idem	Promote social responsibility in local firms
13. 'E-lixo' (E-waste) / Strategy 4 and Strategy 5	1.7%	MCT / idem	Map use of electronic equipment and its waste at Porto Digital. Foster local firms' environmental responsibility
14. Porto Digital Institutional Promotion / Strategy 5 and Strategy 6	3.6%	FINEP / FINEP and SECTMA	Improve Porto Digital's image in other Brazilian regions
15. Porto Digital Press Award / Strategy 5	0.4%	SECTMA / SECTMA and Pernambuco State Press Secretary	Foster specialization of local press in IT related areas
16. Future Projects / Strategy 2 and Strategy 5	4.8%	Not specified	i) improve micro, small and medium firms management skills, ii) Software quality laboratory, iii) institutional strengthening of Porto Digital

Legend: *= Total budget US$9.1M.
Source: own elaboration from NGPD (2009b).

According to NGPD (2009b: 5), which provides an assessment of all actions that were implemented for each of the strategies presented in Table 4.3 (p. 123), NGPD had to postpone implementation of the Strategy Plan for six months due, among other reasons, to the need to seek replacement funding.[216]

The official statement from the state government regarding SECTMA's reduced financial support for Porto Digital was that: i) SECTMA had invested most of its budget in the software industry over the previous five years (2000-2005) and had neglected other industries; this situation needed to be reassessed; ii) Porto Digital had achieved a stage of maturity where it could manage without SECTMA's financial support.[217] However, political issues seem also to have played a role, as da Silva (2008: 7) highlights:

> The year 2006 was also marked by elections for the state government that, after eight years, was won by a political party from the opposition to the previous Government. For the first time since its creation, Porto Digital would have to negotiate state political support and investment with a government from the opposition.

Hence, the initial intention to insulate the Porto Digital programme against political changes did not survive the election of a new government, which argued that conditions had changed and so had funding priorities. The changes in financial circumstances suggested that NGPD was not able to ring-fence public revenue sources, that is, it was not able to achieve political support across party lines as part of state industrial policy. Public stakeholders began to question whether the software industry should be prioritised in state industrial policy. Some held the view that the electronics industry should also be favoured.[218]

Although the state government in power in 2009 claimed that Porto Digital had achieved maturity and should be financially independent of SECTMA funding, the reduction in funding to support the development of Porto Digital suggests a partial

---

[216] The other reasons for the delayed implementation of the Strategy Plan were: i) elaboration of a Strategic Plan for 2010-2020; and ii) late access to financial resources for implementation.

[217] Recife fieldwork organisational interview. However, several interviewees claimed that SECTMA's reduced financial support for Porto Digital was politically related (11 interviewees made this comment, but asked to remain anonymous). Interviewees claimed that the real reason for the decrease in SECTMA's financial support was the change in the state government's political party in the state government elections in 2006. They claimed that the new governor was from the opposition party and deliberately withdrew support from Porto Digital, because this was an initiative formulated and implemented during the previous administration.

[218] Although the shift in the policy programmes of different political parties is a common characteristic of Brazilian public policy programmes, we find similar phenomena elsewhere – see Rhodes (2007) for the UK.

discontinuity in the original policy programme implemented in 2000, which is a problem common to policy programmes in Brazil as discussed by Velho and Saenz (2002).[219]

Under the new state government administration (beginning in 2007) SECTMA has directed funding to Parqtel, an electro-electronics Technological Park that was created in the mid 1990s, but had been virtually abandoned for almost eight years.[220] In March 2008 SECTMA set up a budget of US$5.3M for Parqtel's redevelopment, which was in addition to US$2M from FINEP (SECTMA negotiated this financial support with the Brazilian Ministry of Science and Technology-MCT) for facilities buildings.[221] These amounts are considerably higher than the US$1M that SECTMA set aside for Porto Digital for 2009-2012.

Although SECTMA's financial support has been reduced, there is some evidence that the state government has implemented policies to support the local software industry through government procurement.[222] NGPD and Softex-Recife played important roles as mediators between state government and local software producers (see Chapter 6).

It is difficult to conclude to what extent differences in the visions of the local political parties on strategic priorities in state level industrial policies, shifted the initial policy (i.e. creation of Porto Digital). This issue is beyond the scope of this thesis and is not discussed further. However, we can provide a general overview of the reasons that perhaps influenced government policy. Firstly, there were clear differences in the political parties' industrial policy priorities. These differences are reflected by the actions of public organisations at both city and state levels, for instance in the provision and maintenance of the local infrastructure in Porto Digital. In addition, local stakeholders (e.g. NGPD) were not capable of negotiating continued investment. As a result, NGPD faced funding difficulties with the change in the state government administration in 2007, and had to find alternative funding

[219] See also Chapter 3 above.
[220] Recife interviews numbers 1, 12, 14, 21, 30.
[221] http://computerworld.uol.com.br/negocios/2008/03/10/parque-tecnologico-de-pernambuco-recebe-r-20-66-milhoes-do-mct/, accessed 21 March 2010.
[222] Recife interviews numbers 1, 8, 20 and 21.

sources.[223] This caused delays and some cancellations of some of the strategies related to the 86 goals (NGPD, 2009b).

The above discussion shows that technology policies to support the Recife software industry were implemented mainly at state level. However, the engagement of local organisations and local government was extremely relevant for the region's IT industry catch-up to the national level. Several initiatives fostered the creation of local software firms (see Section 4.3.4).

4.3.4 The Recife software firms and the main actors in the network

According to National Classification of Economic Activities (CNAE) coordinated by the National Classification Commission (CONCLA, IBGE), in 2009 there were 103 software firms based in Recife. Table 4.6 presents the numbers of firms and employees by CNAE categories.[224]

Table 4.6 Recife software firms by CNAE Classification (2009)

Software related IT activities	No. of firms	(%)	No. of employees	(%)	Average no. of employees
Customised computer program development	26	25.2	701	27.2	27.0
Development and licensing of customised computer	13	12.6	293	11.4	22.5
Development and licensing of non-customised computer	19	18.4	202	7.8	10.6
Consultancy in IT	45	43.7	1383	53.6	30.7
Total	103	100	2579	100	25.0

Legend: n.a.= not applicable.
Source: CNAE/ Comissão Nacional de Classificação, IBGE (2009).

Table 4.6 indicates that most Recife software firms developed consultancy software activities (including market development and software adaptation to user needs), which employ the majority of the local IT labour force, followed by customised computer program development (including Web design). Table 4.6 suggests also that most Recife software firms are micro or small firms, confirmed by the fieldwork data (see Chapter 7). As discussed in Section 4.2.4, this is a common characteristic of the Brazilian software industry. In addition to these local software firms, other network

[223] Recife fieldwork organisational interview.
[224] Box A1 in the Appendix provides a full description of the activities included in each CNAE category.

actors were established in the region related to the development of the Recife local software industry (see Table 4.7).

Table 4.7 Recife network actors

Actor	Year of Foundation	Main activity
APEX-Brasil	1997	Promotion of Brazilian exports
Assespro-PE	1976	Industry association
CESAR	1996	Local R&D centre
CESAR Incubator		Incubator programme
CESAR.edu	2006	Training in IT- Master's and continued education
Cin-UFPE	1974	Training in IT undergraduate, Master's, professional Master's, Doctorate and Post-Doctorate
CNPq	1951	National research council
Criatec-Fund	2007	Venture capital fund/ BNDES and private sector
DEINFO-UFRPE	2005	Training in IT undergraduate
DSC-UPE	2004	Training in IT undergraduate
FACEPE	1989	State level research foundation
FIEPE	1939	Pernambuco Industrial Association
FINEP	1967	Brazilian Innovation Agency
FITec-Recife	2002	R&D centre (founded by MNC)
IEL-PE	1969	Support the improvement of firms' management skills and their entrepreneurial capabilities.
Incubanet	2005	Incubator Association
Incubatep	1990	Incubator programme
INdT-Recife	2006	R&D centre (founded by MNC)
ITEP	1945	Pernambuco Technological Institute/ State level
NGPD	2000	Porto Digital Management Unit
Recife City Council	n.a.	Fiscal incentives to software firms based in Porto Digital
Recife-BEAT	1997	Pre-incubation programme/ Cin-UFPE
Sebrae-PE	1972	Support for micro and small entrepreneurships
SECTMA	1993	Foster scientific, technological and innovation development of Pernambuco
Softex-Recife	1993	Fostering and support local software industry.
UNICAP	n.a.	Training in IT undergraduate

Legend: n.a. = not available
Source: own elaboration from organisations' websites and literature review.

4.3.5 Summary

This section discussed the emergence and evolution of the Recife software network. State government implemented a technology policy to foster the creation of new software firms as well as policies to foster collaboration among established firms to strengthen local firms and increase their competitiveness. The Recife software industry has a good reputation in the Northeast region and nationally. CESAR has strengthened its reputation in Brazil and hence supported strengthening of the region's reputation.

4.4 Summary

This chapter responds to the question raised in Chapter 2, Section 2.4 about existing examinations of network governance, which do not fully address the emergence and evolution of networks, leaving a gap in the study of network governance. Specifically, this chapter introduced and provided historical evidence on the structure of the two networks investigated in this thesis, Campinas and Recife, and examined regional historical events related to the emergence and development of their software industries. The Campinas region historically has benefited from the creation of important public and private IT organisations that have been crucial for the emergence and development of a local software industry. The region also benefited from its geographical location; Campinas is in the most dynamic economic region of Brazil, geographically close to the most dynamic market in the country, it has access to an advanced scientific system and a well developed infrastructure. Hence, the Campinas software industry attracts innovative organisations (national and multinational), which has established a virtuous economic cycle, benefiting the software industry development.

The Recife software industry does not have similar advantages, especially in terms of national government technology policies related to funding for the emergence or improvement of institutions developing scientific or technological activities (Cin-UFPE is an exception because it is part of a federal university). Recife is in the Northeast of Brazil, in a region that is economically lagging on most measures, is distant from the most dynamic demand markets in the country, has a diminished scientific system and an under-developed infrastructure compared to other Brazilian regions. However, since the mid 1990s a series of local initiatives at different government levels and from local organisations (mainly private but also non-profit organisations) have promoted the development of the Recife software industry. These initiatives show high levels of coordination, and have played an important role in the development of the Recife software industry and increased its reputation at national level.

Although the historical patterns of these two regions IT industries differ, we found similarities that suggest comparison between them would be fruitful. Firstly, each region hosts one public research university that supports the provision of high skilled human resources in the field of computing science, and both universities show similar academic performance. Secondly, the two regions have been involved in the Softex Programme. Thirdly, the number of local software firms in each region is similar. However, further investigation of the innovation activities of the firms in the two networks is required, in order to find differences and similarities between their activities and their technological capabilities in software development. Chapter 5 describes the methodology used for this research to support the investigations of the Campinas and Recife networks of innovators in Chapters 6 and 7 respectively.

CHAPTER 5 - RESEARCH METHOD

5.1 Introduction

This chapter describes the research method used for this thesis. Chapter 2 showed that there is a number of issues that are rather overlooked by the literature. First, there is much less empirical evidence on multi-organisational interaction than on single organisations interactions despite the apparently increasing importance of larger networks of interacting firms (Provan and Kenis, 2008), in developed and developing countries (Bell and Albu, 1999). Also, studies of multi-organisational networks tend not to investigate the controlling mechanisms within multi-organisational networks. Second, the literature does not provide consistent evidence on which types of conditions, specifically with regard to network governance and structure, are necessary to foster the formation of network ties that might be expected to have a positive effect on firm performance (Giuliani, 2010).

The methodology described in this chapter is complemented by the empirical chapters (6 and 7), which operationalise and apply the core concepts (i.e. the connection between objects and modes of analysis).

This chapter is organised in six sections. Section 5.2 re-introduces the overarching research questions and discusses how they are addressed using the comparative case study approach that is the main approach used in this thesis. Section 5.3 discusses the core concepts and introduces the analytical framework. Section 5.4 discusses the research strategy, justifying the choice of a multiple case study methodology and the units of analysis used. Section 5.5 describes the data collection and data analysis methods and Section 5.6 summarises the chapter.

5.2 Research questions and the broad approach

First we reintroduce the research questions developed in Chapter 2 (Section 5.2.1) and describe the bounded focus of the thesis (Section 5.2.2).

5.2.1 Research questions

This doctoral research is aimed at providing empirical evidence in order to elucidate two issues. The first is related to the formation of multi-organisational ties and why and how local firms in a developing country context, engage in networks. The second relates to which types of conditions are necessary to foster the formation of ties that support positive firm performance in a developing country context, for instance, technological capabilities accumulation and innovation in firms. These conditions may relate to government intervention through the implementation of technology policy to support network formation, or to firms' spontaneous decisions to interact with network actors. To address these issues the research questions are grouped into two sets, A and B, with two questions in each group.

Research Questions Group A:

Question A1

In considering government technology policy to promote firm innovation through networks in a developing country context, do regional level network governance and structure influence policy effectiveness? If they do, what features of governance and structure should be taken into account in policymaking?

Question A2

What, if any, is the responsiveness of network governance and structure to technology policy aimed at the promotion of networks in a developing country context? Does government policy promotion of networks and efforts to control network structure increase the effectiveness of technology policy aimed at improving innovative performance in a developing country context?

Research Questions Group B:

Question B1

Do network governance and structure have a consistent influence upon the innovative performance of developing country firms set up in regions with different socio-economic development indicators?

Question B2

In assessing the effectiveness of technology policy in developing countries, are there differences in policy effects when comparing advanced and relatively backward regions within a country?

That networks are built or emerge in situated contexts in which path-rigidity and 'history' matter is significant (see Chapter 2); we find that the research questions set out above can be answered best by considering the accumulated evidence derived from specific cases. The collection of evidence must be based on in-depth and well documented cases. The need for detailed cases means that a single-investigator study cannot develop a large number of cases (see Section 5.4.2) within a limited timeframe (such as a period of DPhil study). We need, therefore, to choose comparable cases that can provide answers to specific research questions (see Section 5.4.2) and provide insights for the setting of priorities for future investigations. This thesis aims to provide evidence on the basis of which we can make claims that contribute to answering the research questions but not that the results necessarily are generalisable to other contexts. Nevertheless, we hope to contribute to the existing knowledge by addressing some shortcomings in the literature reviewed in Chapter 2 and in the introduction to this chapter. On this basis, we re-formulate the research questions, as follows:

Research Questions Group A:

Research Question A1

In considering government technology policy to promote firm innovation through networks in the case of the two Brazilian regions selected for analysis, how does regional level network governance and structure influence the effectiveness of policies supporting network creation in Brazil?

Research Question A2

What, if any, is the responsiveness of network governance and structure to technology policy aimed at the promotion of networks in Brazil? Does government policy promotion of networks and efforts to control network structure increase the effectiveness of technology policy aimed at improving the innovative performance of Brazilian software firms?

Research Questions Group B:

Research Question B1

Do network governance and structure have a consistent influence upon the innovative performance of Brazilian software firms set up in the two regions selected for analysis?

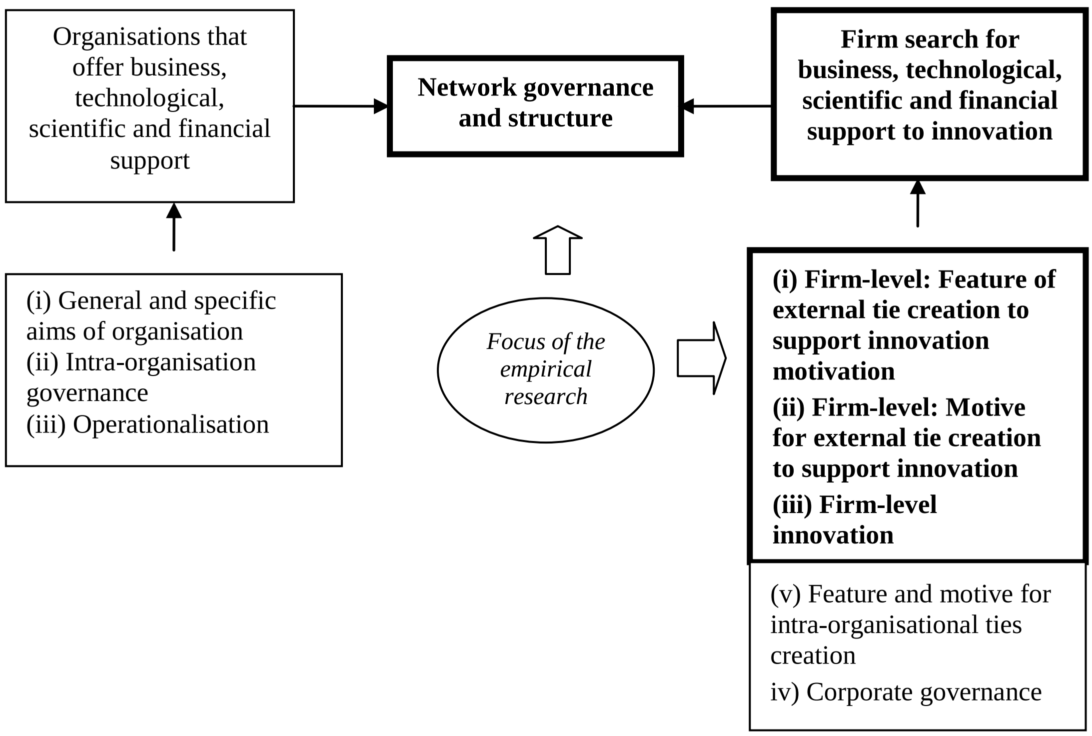
Research Question B2

In assessing the effectiveness of technology policy in Brazil, are there relative differences in policy effects when comparing the two Brazilian regions analysed?

5.2.2 The bounded focus of the empirical research

The literature review in Chapter 2 shows that the innovation systems in which firms are embedded are relevant to support sectors', regions' or countries' socio-economic development (Asheim and Gertler, 2004; Freeman, 1987; Lundvall, 1992b; Malerba, 2004; Nelson, 1993). This is because firms are at the core of the innovation system, and if we consider that networks are a sub-set of systems, then firms are also at the core of innovation networks. It has been acknowledged that developing countries often have dysfunctional innovation systems in which missing or weak links among system components are frequent (Bell and Albu, 1999; Bell and Pavitt, 1993; Cassiolato and Lastres, 1999; Cassiolato *et al.*, 2003; Cassiolato *et al.*, 2008a; Chaminade and Vang, 2008; Dantas and Bell, 2009; Freeman, 2002; Padilla-Pérez *et al.*, 2009; Steinmueller, 2001; Viotti, 2000). Therefore, a comprehensive understanding of how innovation networks emerge and function in developing countries is important. While acknowledging that the system's components are important, this thesis focuses on firms, and on their interactions to support innovation.

Figure 5.1 Focus of the Thesis



Source: own-elaboration, based on the literature review (Chapter 2 in this thesis), and adapted from de Campos (2006).

Figure 5.1 shows that intra-firm interactions can be relevant for firms' innovative performances; however, we focus in particular on the ties among firms, and between firms and other organisations in the innovation system. We focus only on ties created to support firm innovation. This focus on firms' inter-organisational ties is based on the argument in innovation studies that learning by interaction is relevant for firms' technological capabilities building and, therefore, their innovation skills.

5.3 Core concepts and analytical framework

The research questions introduced in Section 5.2 encompass the following key concepts: (i) technology policy, (ii) network governance and structure, and (ii) firm-level innovation. Each concept is discussed below.

5.3.1 Technology policy and regional network creation

The literature review (Chapter 2) discussed the relevance of government intervention in the economy through the implementation of technology policy, based on the argument that technology is a partial public good. The thesis adopts the technology policy definition that: ‘policies… are intended to influence the decisions of firms to develop, commercialize or adopt new technologies’ (Mowery, 1995: 514). Therefore, technology policy covers a wide array of policy actions. Here, we focus on technology policies to foster or support the creation of networks. Chapter 2 (Section 2.2.2) identified the main channels of government intervention to foster or support the formation of networks: i) specification and funding of the emergence of or improvement to organisations that develop any kind of S&T activity; ii) imposition of new regulation in order to improve the relation among actors and agents involved in technological activities and innovation; iii) investment in basic research, higher education, public procurement, subsidies and tax reductions (i.e. direct technology policies); iv) basic education and training standards, competition policy, and public investments (i.e. indirect technology policies). As discussed in Mowery (1995), his definition of technology policy particularly emphasises the intentionality of policy intervention; this is because other government policies, for example, macro-economic policy, may also influence private sector investment in technology. This thesis refers only to explicit technology policies implemented by government and especially those related to network formation. In other words, it focuses on item ii) and those organisations related to network development in item i), and takes as background or context, issues in iii) and iv) in the above list.

5.3.2 Network governance

As discussed in Chapter 2 (Section 2.3), network governance and structure are defined by the three network features of: i) network infancy and evolution; ii) controlling mechanisms within the network, and iii) dyadic ties among firms, and between firms and other network actors. These three features are analysed separately, to enable conclusions to be drawn about how each feature may be contributing to the observed nature and performance of networks.

5.3.2.1 Network infancy and evolution, and the four sub-networks

Network infancy is related to how networks are formed, that is, if they are purposive (following government strategic intervention) or emergent (following spontaneous ties among network actors). This thesis investigates purposive networks and examines two regional networks that were strategically created by the Brazilian government in the early 1990s (see Chapter 3). The two networks were created within the same government programme and, therefore, followed the same initial institutional framework. Chapter 3 shows that the government programme for the creation of software networks in different Brazilian regions was inspired by the systems of innovation approach, and assumes that networked firms will be better supported in their innovation activities by ties among themselves or with other components of the innovation system, such as universities, research centres, supporting organisations and funding agencies.

The networks investigated in this thesis were identified by a priori identification of organisations that are part (or should be part) of the network. Network actors were identified through public reports, academic studies and specialised press on the technology policies implemented in Brazil (Chapter 3) and in the two investigated networks (Chapter 4).[225]

The network approach employed in this thesis considers innovations networks include the following organisations: Brazilian owned firms, suppliers, customers, public agencies, associations, universities, technical institutes, research foundations, laboratories, technology centres, public and private banking systems, and government (local and regional). We categorised these organisations into four sub-networks: business, skills, technological and financial.[226] The rationale for grouping the actors into these sub-networks follows the argument that innovation networks are a sub-set of systems of innovation. Hence, network actors that belong to the same 'group' of components within the innovation systems have overlapping aims and can be grouped accordingly.

[225] Some firms were identified as network members through interviews, which helped the identification of networks, see Section 5.5.1.
[226] The possibility was considered to include IT MNCs in the interview sample of business network agents if local firms identified them as collaborators. However, none of the Brazilian-owned software firms interviewed mentioned multinationals as collaborators for innovation so MNCs are not included in the interview sample.

The technology sub-network is composed of organisations that perform basic or applied R&D in IT areas, either for their own commercialization or as outsourced providers of services to IT firms.

The skills sub-network is composed of organisations devoted to IT training at different levels, such as undergraduate, Masters, Doctoral, Post-Doctoral and continuing education, the research foundations that provide funding for training at different educational levels and the programmes that support R&D in firms (including the IT area of knowledge).

The business sub-network is composed of organisations that support software firms by: i) networking with customers and other software development firms, ii) providing support for applications to public funding institutions, iii) consortium formation, iv) access to information on national and international markets, v) provision of facilities for software development (e.g. software testing laboratories) and training in relevant areas (e.g., ‘agile methodologies’ for software development), and vi) specific support for micro and small firms (including designing business plans, training in organisational matters and market entry).

The financial sub-network is composed of private and public funding organisations and agencies. The former include the private banking system and venture capitalists. The latter are organisations and agencies that support firms and other network actors financially, to perform basic and applied research and innovation in the IT industry (although they may finance other areas than just IT). Financial support can be provided through loans, reimbursable grants, non-reimbursable grants, tax incentives and special programmes (e.g., funding for technological park creation), etc. Government bodies are included in the financial network, because government authorities can provide financial assistance to firms through one of the means mentioned above. Therefore, local and state governments are included in the financial sub-network, as well as government authorities operating at national level.

5.3.2.2 Controlling mechanisms

The investigation of controlling mechanisms allows the identification of brokered networks, shared-governance networks, and mixed governance networks. Brokers concentrate power within the network; however their engagement in the network through the creation of dyadic ties is not necessarily a pre-requisite (i.e. they can be either internal or external to the networks). In shared-governance networks we find that power is spread among network participants, hence, these participants are engaged in the network through dyadic ties. In mixed governance networks we find that some actors are responsible for coordinating certain issues, others being collectively coordinated. Mixed governance networks suggest a higher probability of hierarchical arrangements within the network than in shared governance networks.

Investigation of how controlling mechanisms are exercised within a network supports an understanding of whether coordination within the network is concentrated in a few actors, which has implications for the evolution of the network. The possibility of these actors withdrawing from the network at any time compromises its evolution. Also, as discussed in Chapter 2, the identification of heterarchical (shared-governance) or hierarchical (brokered) control in networks may support the formulation and implementation of technology policy aimed at creating or supporting network formation.

5.3.2.3 Dyadic ties

The investigation of dyadic ties supports an examination of network governance by providing evidence on: i) number of collaborating actors for each firm; ii) type of actors tied to firms; iii) frequency of collaboration with each actor; iv) tightness of the ties among actors; v) consistency between sub-networks; vi) level of openness of the network; and vii) the structure of the network. We discuss each of the indicators constructed to examine network governance.

The number of ties created by each firm together with the types of actors involved shows the extent to which firms rely on internal or external support for innovation, and the type of external support they search for, that is, technological, scientific, business or financial. We examine the frequency of ties for support in terms of whether they are used on a ‘one-off’ or regular basis.

The tightness of ties relates to the motivation for firms to create external formal ties with network actors and the frequency of ties. The composition of this indicator was inspired by the work of Granovetter (1973), who defines strong ties as direct, trust based, and long-term, and weak ties as indirect, more opportunity based and short-term. The thesis analyses only direct ties, to investigate whether the creation of direct ties involves (mainly) the characteristics associated with strong or weak ties as discussed by Granovetter. We define direct ties as tightly-connected ties, that is, ties based on trust, affiliation, collective identity and knowledge availability and accessibility; tightly-connected ties are supposedly less vulnerable to breaking under pressure. Conversely, loosely-connected ties are also direct whether based on opportunity or cost, and are supposedly more vulnerable to breaking under pressure. We investigate also whether geographical proximity supports the creation of tightly-connected or loosely-connected ties. Firms were asked about motivations for tie creation additional to those listed in the questionnaire (see above).

The consistency of the sub-networks indicator relates to the overlap between the features of ties created by firms with other network actors, the general aims of the sub-network to which the actor belongs, and the self-defined, specific aim of the tied actor. Hence, consistency provides an evaluation of the performance of tied organisations. The composition of this indicator follows the Oslo Manual classification for the nature of external relationships among actors (OECD, 2005). The indicator is based on six features of the ties created by each firm with network actors: i) access to open information; ii) acquisition of knowledge; iii) acquisition of technology; iv) access to new sources of finance; v) access to commercial information; and vi) innovation co-operation. Table 5.1 summarises the consistency of each of the four sub-networks investigated in the thesis, that is, business, skills, technology and financial sub-networks.

Table 5.1 Indicators for consistency of sub-networks[227]

Sub-network	Type of sub-network actor	General aims by sub-network	Features indicating consistency
Business	a) industrial associations b) competitors c) customers d) suppliers e) consultancy firms f) incubators g) private non-profit organisations acting on behalf of the public interests	i) foster and support interactions among firms and between firms and customers ii) support for research funding applications iii) access to information on national and international markets iv) provision of facilities or knowledge for software development, training and workshops v) support the design of business plans and training on organisational matters vi) support software process improvement vii) incubation programmes	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Access to new sources of financing 5. Access to commercial information 6. Innovation co-operation
Skills	a) universities b) technical colleges c) continued education organisations d) research council e) research foundation	i) IT training in different levels, such as undergraduate, Masters, Doctorate and Post-Doctorate and continued education; ii) support new knowledge creation through basic or applied research funding programmes; iii) support new knowledge creation through funding programmes for development activities.	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Innovation co-operation
Technology	a) research organisations b) development organisations	i) perform basic or applied research for, among others, the commercialisation by the private sector ii) development activities for, among others, the commercialisation by the private sector.	1. Acquisition of knowledge 2. Acquisition of technology 3. Innovation co-operation
Financial	a) private and public banking organisations b) public funding organisations c) venture capitalists d) government authorities	i) grants or loans for firm-level basic or applied research and development activities ii) venture capital for start-ups iii) tax incentives for firm-level innovation activities iv) creation of technological parks or incubation programmes	1. Acquisition of knowledge 2. Acquisition of technology 3. Access to new sources of financing

[227] Consistency here is understood as what von Tunzelmann (2003) calls alignment.

Firms were asked about any additional features not included in the questionnaire list. Validation of the questionnaire revealed that two of the elements discussed in the Oslo Manual had to be adapted. For instance, the Oslo Manual assumes acquisition of knowledge and technology require payment through a purchase process. According to the sampled software firms, they were able to acquire new knowledge and technology without payment.

The openness level of the network relates to the geographical localisation of collaborating network actors. The two investigated networks are based in different regions; therefore, whenever we found that tied actors were mainly intra-region actors the regional network was classified as close. Correspondingly, if there was a presence of inter-regional tied actors (from another Brazilian region or from abroad), the regional network was classified as open. The openness level supports conclusions about the regional network's vulnerability to lock-in, that is, the network has a high level of cooperation and cohesion, but may see outsiders as a threat to their adaptability and capabilities to innovate (Grabher, 1993; Grasenick *et al.*, 2008; Semlinger, 2008).

The structure of the network refers to how the network actors are connected in terms of being classified as fragmented or well-knit. Fragmented networks occur when the number of indirect ties is small, that is, network actors are frequently isolated. Conversely, well-knit networks occur when the number of indirect ties is high, and network actors are have frequent–direct or indirect- connections (intermediate stages between fragmented and well-knit are possible, and the visualisation of the network, see Section 5.2.2, supports our conclusions on the structure of the network).[228] Table 5.2 summarises the network governance indicators discussed above and suggests possible network outcomes related to each indicator. These indicators are characterisations of the *predominant* network outcomes expected and are derived from the literature (Chapter 2). The case studies investigated in Chapters 6 and 7 qualify the dominant characterisations of network outcomes.

[228] Well-knit is used in this thesis to classify the structure of the network; it refers to how ties among the members of the network are connected. The higher the number of connected ties among themselves, the higher is the likelihood of a healthier/stronger network. This follows the system of innovation and network of innovator approaches, where connections are crucial for learning by interacting. Well-knit derives from medical terminology to describe the healing process of broken bones: those that join firmly are described as well-knit.

Table 5.2 Summary of network governance indicators

Network governance indicators	Network features	Possible outcomes
Tightness	Tightly-connected ties	i) Lower vulnerability to break when put under pressure ii) More reliability in the transmission of information within the network
	Loosely-connected ties	i) Higher vulnerability to break when put under pressure ii) Less reliability in the transmission of information within the network
Structure	Well-knit network	i) Lower probability of missing links among actors
	Fragmented network	i) Higher probability of missing links among actors
Consistency	Consistent sub-network	i) High occurrence of overlapping aims ii) Higher chance of policy effective results
	Inconsistent sub-network	i) Low occurrence of overlapping aims ii) Lower chance of policy effective results
Openness	Intra-regional ties only	i) Higher vulnerability to lock-in ii) Lower absorptive capacity
	Intra and inter-regional ties	i) Lower vulnerability to lock-in ii) Higher absorptive capacity

Source: own elaboration based on literature review (Chapter 2).

5.3.4 Firms' innovation

As discussed in Chapter 2, the definition of innovation in the Oslo Manual (OECD, 2005) accommodates the innovative performance of developing country firms. Therefore, the definition is appropriate to investigate innovation in Brazilian software firms. According to the Olso Manual:

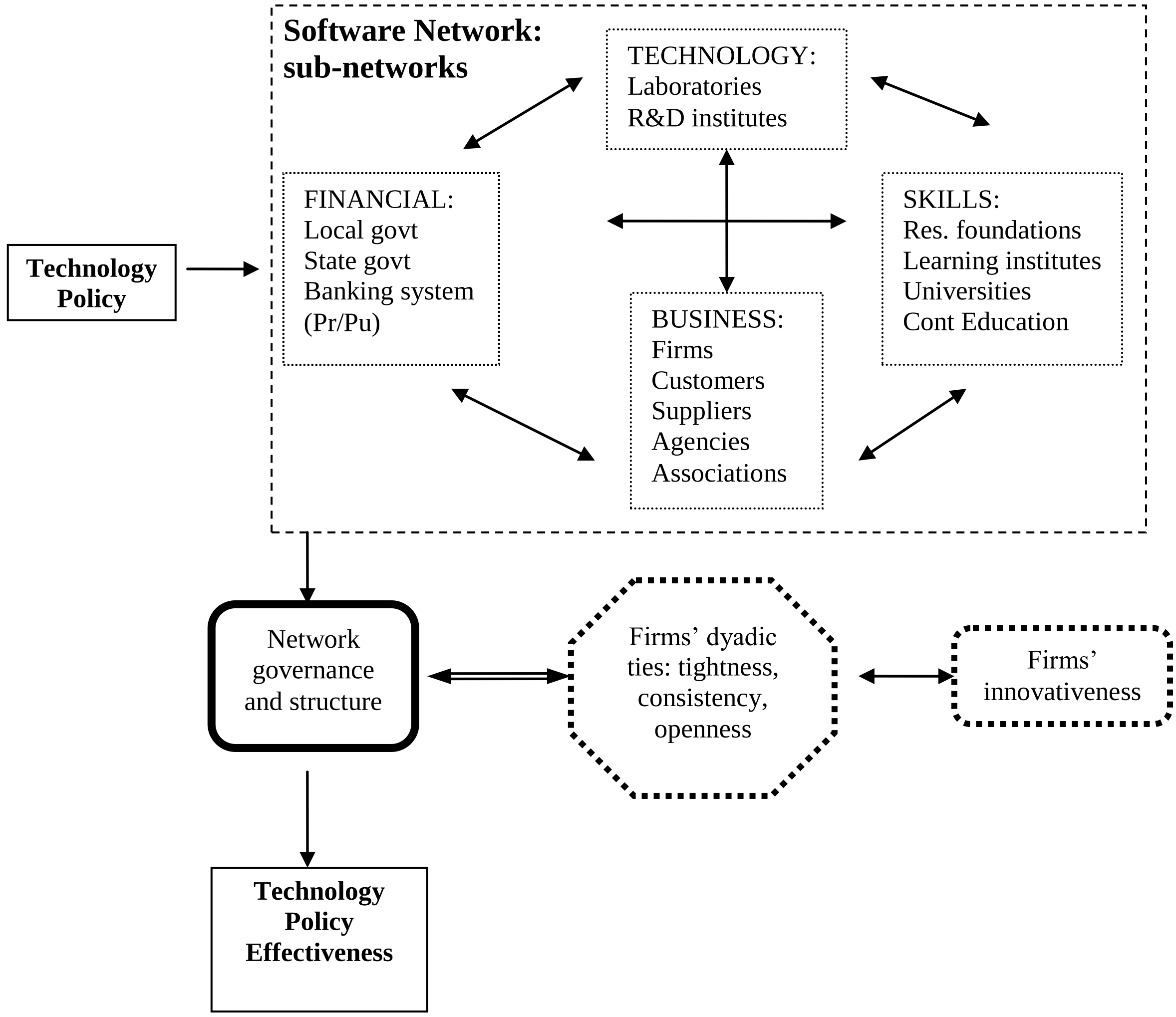
> an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (OECD, 2005: 46).

In addition, an innovation can be classified according to its degree of novelty, as follows: i) firm-level (i.e. new practices or outputs within the firm which are already present in other firms); ii) national market level (i.e. practices or outputs new to firms in the country); and iii) international market level (i.e. new practices or outputs that are new to the world). Innovations are classified also as technology or business related.

Another reason for employing the Oslo Manual definition for innovation is the wide adoption of this definition by innovation surveys in several countries (such as the European Union, Brazil and Australia).[229] Hence, the use of this definition allows comparisons among firms within a network and among different regional levels (including the national and international), and different sectors (OECD, 2005: 139). The core concepts discussed above are summarised in Figure 5.2, which corresponds to the analytical framework for this thesis.

[229] http://www.seade.gov.br/produtos/paep/pdfs/metodo.pdf, accessed 10 March 2001. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/8158.0Explanatory%20Notes12005?OpenDocument, accessed 10 March 2001.

Figure 5.2 Analytical framework



Legend:
→ = mono-directional influencing factor
↔ = bi-directional influencing factor
⇔ = bi-directional influencing and causation factor

Cont= continuing
Govt= government
Pr= private
Pu= public
Res= research

Source: own elaboration, adapted from von Tunzelmann (2010: 16).

Section 5.4 discusses the research strategy for collecting the empirical data, which included: i) choice of appropriate method for answering the thesis research questions; ii) justification for the type of information collected; and iii) explanation of the information sources used to collect the relevant data.

5.4 Research strategy and case design

5.4.1 The case study method

The literature reviewed in Chapter 2 and the empirical evidence on industrial development in Brazil (Chapter 3) show that there is a need to understand how network governance and structure influences the effectiveness of government technology policies aimed at promoting regional development in a developing country context. According to Yin (2003: 6-9), 'how' and 'why' type research questions are more explanatory (in the case here looking at how one phenomenon may influence another) and are better answered using a case study approach.

We can also justify the choice of a case study approach based on the network governance concept adopted in this thesis. The network governance concept analyses three features of the network: i) infancy and evolution; ii) the dyadic ties between firms and other network agents; and iii) controlling mechanisms applied in the network. These three network features refer to both the contextual conditions and changes over time (especially the evolution of the network and controlling mechanisms). According to Yin (2003: 13), investigations that deal with contextual and temporal phenomena are better explained through a qualitative case study approach.

Studies on governance, such as the Worldwide Governance Indicators developed by the World Bank (Kaufmann *et al.*, 2010), relate governance to *rules* and *traditions* and employ quantitative methods aimed at creating indicators that allow comparison of governance across countries.[230] Studies of governance in the context of networks are often related to *cooperation* and *collaboration* (e.g. Grasenick *et al.*, 2008; Jones *et al.*, 1997; Provan *et al.*, 2009; Semlinger, 2008) and use quantitative methods (such as econometric models and Social Network Analysis) to investigate the structure of networks.

---

[230] http://info.worldbank.org/governance/wgi/sc_country.asp, accessed 17 May 2011.

In contrast to these types of approaches, this thesis understands governance as *coordination* (Chapter 2, Section 2.4.1). In addition, it understands the relation between network structure, ties created by network actors over time, and governance as multivalent; and this type of relation is better addressed using a more qualitative approach. Moreover, a qualitative case study better addresses possible correlations between the positive outcomes of the indicators developed above, the effectiveness of the governance of the network and the innovation performance of firms (see Section 5.5.2).

Although the thesis develops a qualitative case study approach, we complement the methodology by a quantitative approach using the Social Network Analysis software, Pajek, to visualise representation of the network of innovators (see discussion in Section 5.5.2). Although we found that the software network representation was adequate to demonstrate which agents were formally linked within the network, it did not allow discussion and analysis of the data. As explained in Chapter 2, Section 2.4, and Section 5.3.2, the thesis employs a network governance concept that aims to investigate the infancy and evolution of the network, the features and motivation that drive firms to create formal ties with other actors, and controlling mechanisms that may be influencing the network structure. Following Grasenick *et al*'s (2008: 309-310) argument that Social Network Analysis does not capture 'historical tracks, legal restrictions, [and] institutional conditions' that affect cooperation among network actors and, therefore, affect the network structure, we claim that this approach is not completely appropriate to discuss the data presented in this thesis

The nature of the research questions introduced in Section 5.2 and the arguments above justify our choice of a multiple case study methodological approach (Yin, 2003: 42). Moreover, a two case study approach was considered more appropriate to address the research questions. Technology policy directed at regional network creation may have different outcomes due to: i) policy implementation (involving questions such as: were all mechanisms fully implemented or implemented at all?; were all the necessary actors involved so that the policy would be effective?); and ii) the socio-economic and institutional settings where the policy is implemented may differ among regions and economic development stages; both may influence government policy effectiveness. Therefore, two case studies allow comparison among two regions and controlling for the issues raised above. Section 5.4.2 addresses this issue further.

5.4.2 The two case studies and the unit of analysis

The selection of the two case studies was an important step in the research design. Considering the research questions introduced in Section 5.2, we found that the selection of two case studies (two networks) should be based on the following criteria: i) being targeted by government technology policies aiming at regional network creation in a particular industry; ii) being within the same initial government programme, so that the networks would be in the same framework (i.e. receiving similar incentives and following similar regulations); iii) the networks ideally should be based in regions at different stages of industrial development to allow conclusions to be drawn on whether policy effectiveness is linked to different development stages; and iv) the networks ideally should be based in regions with different levels of socio-economic development, to allow conclusions about whether the factors influencing policy effectiveness were the result of the local socio-economic development or the policy implementation. The examination of a larger number of cases, that is, three or more regional networks, would have increased the scope of the thesis beyond what was practically feasible (in terms of time and resources) for a doctoral project.

Following the criteria above, two Brazilian software industry regional networks were selected, Campinas and Recife (see Chapter 4). The two networks were formally created in the early 1990s within the SOFTEX Programme (discussed in Chapter 3, Section 3.3.2), implemented by the Brazilian national government. This refers to selection criteria (i) and (ii) above. The third and fourth criteria were fulfilled by the choice to study two networks that were part of the Softex Programme, and also were located in regions with different levels of software industry and socio-economic development. Campinas is in the Southeast region of Brazil and is considered the country’s leader region in the software industry (Chapter 4, Section 4.2). Recife is in the Brazilian Northeast region and since the mid 1990s has been trying to catch up to Brazil’s leading software industry region (Chapter 4, Section 4.3). Chapters 6 and 7 respectively, investigate the Campinas and Recife networks.

The thesis followed the strategy of holistic multiple case studies discussed by Yin (2003: 46-53). According to Yin, holistic case studies are justified when the cases have different contexts and the identification of sub-units is not possible; which corresponded to the case studies in this thesis.

5.5 Data collection and analysis

5.5.1 Data collection

The data collection was conducted in two phases: (i) pilot fieldwork, implemented in the Campinas network only; and (i) main fieldwork, implemented in both Campinas and Recife networks. Interviews were also conducted in other locations, especially those with government organisations.

(i) Pilot fieldwork

Pilot fieldwork data collection was implemented this choice being based on the literature review on the Softex Programme which claimed that the programme based on the experience of Campinas in the IT industry. The Campinas network was also studied in the main fieldwork. The aims of the pilot fieldwork were to confirm whether the analytical framework and research questions were appropriately designed, and to find a possible network for comparison with the Campinas network. These two aims were fulfilled, as follows: (i) we redesigned and rephrased the analytical framework and research questions on the basis of the pilot fieldwork data analysis; and (ii) interviewees suggested the Recife network as a comparable case, which was justified by the reasons related to case study selection criteria in Section 5.4.2. A total of 12 interviews was conducted during the pilot research with: research centres (2 interviews), research laboratories (1 interview), local research university (5 interviews), Brazilian Development Bank-BNDES (1 interview), Softex representative (1 interview), Brazilian Ministry of Science and Technology (former employee, 1 interview), and supporting institutions (1 interview). The interviews were face-to-face with the exception of the BNDES, which was a telephone interview, and were based on an open-ended questionnaire.

(ii) The main fieldwork

The main fieldwork date collection was implemented mostly in the two networks, Campinas and Recife.[231] The main source of empirical information was face-to-face interviews using semi-structured (majority) and open-ended questionnaires. The questionnaires included different criteria for each type of organization. The firm questionnaire collected data on their innovation processes.[232] Public and private organisations questionnaires collected additional evidence to and validated information from websites, reports and formal studies (data triangulation discussed by Yin (2003: 97)).[233] A total of 91 interviews was conducted, 9 of which were telephone interviews.[234] Table 5.3 presents the interviews by type of organisation.

Table 5.3 Total number of interviews by type of organisation

Type of organisation	Number of interviews Campinas	Number of interviews Recife	Total number of interviews
Consultants	2	1	3
Firms	21	17	38
Government representatives	2	2	13*
Incubators	3	2	5
Research centres	4	4	8
Research foundations	1	2	3
Supporting organisations	7	6	13
University faculties	4	2	6
Venture capital fund	2	0	2**
Total	46	36	91

Legend: *= total number of representative including national government. Number of government representatives interviewed in Campinas=2, Recife=2 and national government= 9.

**= venture capital fund representatives were based in the Campinas city; however their actions covered the Brazilian national territory.

Source: own elaboration from fieldwork data collection.

Other sources of information include: i) administrative documents (e.g. reports); ii) formal studies of websites (e.g. Master's and DPhil dissertations); iii) articles in the mass media; iv) presentations by interviewees and others involved in the networks; v) informal conversations with people knowledgeable about the networks; and vi) as

[231] Two interviews were conducted in another location.

[232] Firm questionnaire collected data on marketing and organizational innovation (Section C); however, the significance of the observations did not merit analysis. Data on dynamics capabilities (questions B23 to B25) and on constraints on innovation (Section D) are out of scope of the thesis and were not analysed.

[233] Appendix 2 provides the questionnaires.

[234] Of these, 8 were conducted over the phone because of the location of the interviewee; in one case the interviewee would only agree to a telephone rather than a face-to-face interview.

participant observer at a local event involving firms and representatives of the main organisations supporting the network. These other sources of information were used i) first to corroborate evidence provided by the interviewees (Yin, 2003) and ii) acquire knowledge about the history of the organisations, the networks, and the formulation and implementation of policies. This last supported questionnaires design and minor modifications to the questionnaires during data collection (validating the questionnaire), mainly by the addition of topics that the researcher had not been aware of.

Selection of interviewees started in the preparation stage for fieldwork data collection. An investigation of the main public and private organizations (including firms) involved in the two networks provided information about which were most relevant. Consultation of these organisations' websites revealed key candidates. One month before the fieldwork, the first prospective interviewees were contacted and appointments arranged. This first group of interviewees recommended others and offered to mediate between the interviewer and other possible interviewees (snow ball technique). In only one case did someone decline to be interviewed, on the grounds of lack of time and interest in participating. Some interviewees had to be prompted in order to make a firm arrangement, especially company interviewees who had been involved in a lot of interviews and research projects conducted by university researchers and saw little or no return from this investment. After the interviews, each interviewee received a formal message of thanks for his or her contribution to the thesis.

Interviews lasted approximately 75 minutes; however some lasted 4 hours and a few less than 45 minutes. Interviewees were asked at the beginning of the interview how much time was available in order to ensure key areas were covered. This was especially crucial for firm interviewees because a structured questionnaire was used.

Interviews were recorded by detailed note taking. The decision not to use tape recording was to encourage greater candour on the part of respondents. It was believed that tape recording would interfere with information disclosure, particularly statements criticising other members of networks. The notes were transcribed immediately after each interview in order to avoid losing relevant information and to reproduce as closely as possible the exact words of interviewees to avoid bias from the interviewer's interpretations. The transcriptions were in Portuguese to ensure accuracy and allow validation by interviewees or others if necessary.

(iii) Sample of firms

The criteria for selecting firms included: size, age, and type of software activity, that is, product or service complexity. The discussion on the Brazilian software industry in Chapter 3 shows that most are micro or small firms (see Araújo, 2011: 244; and Roselino, 2006). The thesis applied the Brazilian Service of Support for Micro and Small Enterprises (Sebrae) criteria to classify firm size based on number of employees: i) micro firm = 1 to 9 employees; ii) small firms = 10 to 49 employees; iii) medium firms = 50 to 99 employees; and iv) large firms = more than 100 employees.[235]

The totals used included permanent and seasonal employees based on the argument that the majority of firms were micro or small firms (80% in Campinas and 70% in Recife) and could not afford to employ most staff on a permanent basis. The numbers of seasonal employees was often higher than the permanent employees. [236] Were we to base the sample on permanent employee numbers, it would be distorted. The criterion of annual turnover was considered but not all firms were happy to disclose their annual turnover and a classification based on this criterion for the whole sample was not feasible. The total sample of firms included 21 firms in Campinas (19.6% of the total population of firms - Chapter 4 Table 4.1) and 17 in Recife (16.3% of the total population of firms - Chapter 4 Table 4.2).

The firms were of different ages and sizes (Tables 5.4 and 5.5), and covered a wide range of production activities (see Appendix Table A2 and Table A3 for Campinas and Recife software firm activities).

---

[235] http://www.sebrae-sc.com.br/leis/default.asp?vcdtexto=4154&%5E%5E; accessed 09 May 2009. The choice of criteria is supported by NGPD criteria to determine Porto Digital firms' size populations: i) micro firm = less than 5 employees; ii) small firms = 6 to 20 employees; iii) medium firms = 21 to 50 employees; and iv) large firms = above 51 employees. According to NGPD, Porto Digital firms are: 49% micro firms, 40% small firms, 11% medium and large firms (Recife fieldwork organisational interviews).

[236] This issue was reported in *The Economist* magazine 10 March 2011, in an article claiming that the financial penalty for firms making permanent employees redundant combined with very high employee turnover has led to a strong bias towards temporary employment contracts in the Brazilian market, http://www.economist.com/node/18332906, accessed 09 May 2011.

Table 5.4 Campinas software firms' profile (age and size)

Age/Size	Micro	Small	Medium	Large
Younger than 5 years	Firm 2 Firm 6 Firm 8 Firm 10 Firm 11 Firm 16 Firm 19	Firm 12 Firm 14	0	0
6 to 10 years	Firm 7 Firm 17	Firm 3 Firm 5 Firm 9	0	Firm 15 Firm 18
11 to 15 years	0	Firm 4 Firm 13 Firm 20	0	Firm 1
16 to 20 years	0	0	0	0
Older than 21 years	0	0	0	Firm 21

Source: fieldwork data collection, May and June 2009.

As already mentioned, before data collection began we identified and pre-selected innovative firms for interviews in both regions, and these firms were included in the sample. The 'snow ball' technique used to support the identification and inclusion of innovative firms that were not immediately identified through consultation with public reports, academic studies and specialised press proved valuable. The in-depth interviews with firms using a semi-structured questionnaire allowed identification of patterns among firms in both regions (see Chapters 6 and 7).

Table 5.5 Recife software firms profile (age and size)

Age/Size	Micro	Small	Medium	Large
Younger than 5 years	Firm 3	Firm 5 Firm 7 Firm 8	Firm 13	Firm 2
6 to 10 years	0	Firm 10 Firm 11 Firm 12 Firm 14	0	0
11 to 15 years	0	Firm 4 Firm 6 Firm 17	Firm 16	0
16 to 20 years	0	Firm 15	0	Firm 9
Older than 21 years	0	0	0	Firm 1

Source: fieldwork data collection, April 2009.

5.5.2 Data analysis

Data analysis occurred in three stages. The first comprised transcription of interview notes to produce a comprehensive and accessible database that would allow further consultation as data analysis proceeded, and support the creation of comparable data among the units of analysis. The first step consisted of transcription in the original language (Portuguese) and then translation into English, both using Microsoft Word. In a second step, the initial data transcriptions were used as the basis for Excel worksheets, which aggregated comparable variables for each interview category (e.g., firms, supporting organisations, government representatives, academics). The worksheets supported the creation of a set of tables that classified the collected information, and supported the creation of a link between the core concepts applied in the thesis and the empirical information gathered during the data collection.

The second stage involved the compilation of tables classifying the information collected to construct indicators of network governance (network tie tightness, structure, consistency and openness).

Table 5.6 presents the indicators conceptually defined in Table 5.2 made operational for the purposes of measurement. In potential network features we find that 'higher' and 'lower' are relative terms that are meant to apply to the range of observed values; we identify characterisations of *predominant* network outcomes, and not optimal values.

Table 5.6 Network governance indicators and variables for analysis

Network governance indicators	Variable	Potential network features
Tightness	Motivation for external tie creation by each firm and frequency of ties occurrence	i) Higher number and frequency of strong ties= tightly-connected ties; ii) Lower number and frequency of strong ties= loosely-connected ties.
Structure	Number of external ties created by each firm	i) Higher number of ties among local firms and network actors= well-knit network; ii) Lower number of ties among local firms and network actors= fragmented network.
Consistency	Feature of external tie created by each firm	i) High overlap between feature of external tie created by each firm and aims of each network actor= consistent network; ii) Low overlap between feature of external tie created by each firm and aims of each network actor= inconsistent network.
Openness	Geographical location of each collaborator	i) Higher number and frequency of intra-network collaboration= close-like network; ii) Higher number and frequency of inter-network collaboration= open-like network.

Source: own elaboration based on literature review (Chapter 2).

For reasons of confidentiality, the data in this thesis have been codified to ensure anonymity of interviewees. The interviews are split into three groups: Campinas, Recife and Brasil, the third group referring to interviews with central government controlled, public organisations. The list of representatives interviewed is provided in Appendix Table A4.[237]

The third stage of data analysis comprised analysis of the variables in Table 5.6, using the network governance indicators to understand and explain possible relationships among them. The first step involved identification of patterns within the two networks for each of the three innovation stages analysed for each firm; that is, commercialised innovations during the period April 2006-June 2009, ongoing

[237] The full list of organisations and interviewees is available to examiners only.

innovations during the period April 2006-June 2009, and abandoned innovation attempts during April 2006-June 2009, which were related to the questions in Group A. The second step was to identify possible patterns and contradictions between the two networks, to respond to the research questions in Group B.

In this third stage, quantitative research methods and Social Network Analysis software Pajek were used to support individual visual representation of the two networks for each innovation stage analysed. Visual representation supported the identification of patterns within the network, such as tightness of firms' external ties, structure of the network and network level of openness. For tie tightness, we used Pajek to differentiate tightly-connected from loosely-conencted ties (the former represented by thick lines and the latter by thin lines in Chapter 6 - Figures 6.1, 6.2 and 6.3, and Chapter 7 – Figures 7.1, 7.2 and 7.3).

Types of network actor were differentiated by symbols and colours which allowed the identification of patterns within the network with regard to the type of actors and their predominance. Visual representation of the networks also supported identification of network structure, that is, well-knit or fragmented. We were able to identify controlling mechanisms within the network, that is, whether the network was hierarchical, heterarchical or shared-governance. This supported conclusions on two issues: i) the role of actors exerting the most power within the network, and the possible effects on the network were they to leave it; and ii) the presence or absence of important actors who might be expected to join the network.

Finally, examination of the networks of innovators employing the indicators developed above and the use of Pajek to visualise the network, allowed conclusions about the structure and transaction completeness of the networks. Whenever these network features showed more positive outcomes we concluded that the governance of the network was more effective; conversely, when they were less positive the governance of the network was less effective. Governance effectiveness then was related to the innovation performance of the sampled firms allowing propositions about whether more effective governance led to better firm innovation performance. Chapters 6, 7 and 8 continue this discussion in relation to the thesis research questions.

5.6 Conclusion

This chapter introduces the methodology adopted in this thesis, which is complemented by explanation and development of the operationalisation of the core concepts applied in the thesis. This is developed further in the empirical chapters (6 and 7).

The research questions were re-introduced and re-specified according to the situated nature of the current study which is meant to deliver tentative conclusions on the over-arching questions and specific answers to the situated versions of the questions. This was followed by a detailed explanation of the bounded focus of the empirical research (Section 5.2), presentation and summary of the core concepts in an analytical framework (Section 5.3 and Figure 5.2). We presented the rationale for the research strategy, justifying a multiple case study method, selection of the two case studies and the units of analysis used (Section 5.4). Section 5.5 described the procedures used to collect and analyse the empirical data which form the basis for the discussion and concluding analysis in Chapter 8.

CHAPTER 6 - EMPIRICAL RESULTS I: THE CAMPINAS SOFTWARE NETWORK

6.1 Introduction

This chapter investigates the governance of the Campinas regional software network during the period 2006-2009, and how network governance and structure may have influenced Campinas software firms' innovative performances in that period. Chapter 4 described the structure of the Campinas network and the region's long history with ICT; it discussed government policies implemented since the early 1990s to support the region's software development. The region's history and the implementation of government policies (although not centrally coordinated) have favoured the emergence and development of the Campinas software industry, and supported the region's becoming the leading Brazilian software region.

Chapter 6 exploits the indicators developed in Chapter 5 to investigate the features and motivations for the creation of formal dyadic ties by firms to support their innovation activities, and indicators to measure innovation at firm level. Chapter 5 showed that the Campinas software network was defined prior to the empirical data collection and here we want to find whether there are relations between network members and how they interact. Section 6.2 addresses the *structural* embeddedness of the governance of the Campinas network of innovators based on the features of dyadic ties created by firms which are indicative of the consistency of the four sub-networks examined (i.e. business, skills, technology, financial).

Section 6.3 addresses issues related to the *relational* embeddedness of the governance of the Campinas network of innovators, based on the motivation for the dyadic ties created by firms and the tightness of ties – that is, tightly or loosely-connected ties (where tightness is determined by motivation for and the frequency of ties). We provide a visual representation of the network of innovators and investigate those organisations that function (and are likely to function) as bridges within the network.

Section 6.4 examines Campinas software innovations at firm level for each innovation stage examined – that is, commercialised, ongoing and abandoned, to identify which firms are innovating and whether they are connected or disconnected to the main cluster of network nodes. We identify the degree of novelty of their innovations: i) firm innovation (i.e. new practices or outputs for the focal firm already existing in other firms); ii) national market innovation (i.e. practices or outputs new to firms in Brazil); iii) international market innovation (i.e. practices or outputs new to the world). Section 6.5 introduces a few observations on the catching-up process of Campinas software firms. Section 6.6 concludes, summarising evidence that contributes to answering the research questions in Group A (see Chapter 5).

6.2 The Campinas network of innovators: tie creation and consistency of the four sub-networks

This section investigates the consistency of the business, skills, technology and financial sub-networks. Consistency is indicated by the level of overlap between the feature of the ties created by firms and the stated, self-defined aims of the tied organisations. We discuss the three innovation stages - commercialised, ongoing and abandoned – in relation to each sub-network. The empirical findings on the feature of innovation related ties created by firms provide evidence of the consistency of the sub-networks. Section 6.2.1 addresses the business sub-network, Section 6.2.2 the skills sub-network, Section 6.2.3 the technology and Section 6.2.4 the financial sub-network. Section 6.2.5 summarises Section 6.2.

6.2.1 Consistency of the business sub-network

The business sub-network was the most accessed by Campinas local software firms, that is, firms had more ties with business sub-network actors than with the other three sub-networks, for all the innovation stages investigated. The results are as follows: i) 10 firms created 11 ties with 5 types of actors for commercialised innovations; ii) 6 firms created 10 ties with 4 types of actors for ongoing innovation; and iii) 2 firms created 2 ties with 2 types of actors in the case of later abandoned innovations. This result might be expected because there are more actors in the business sub-network than in the other three ones, however, the total number of ties created was not necessarily expected to be higher than in the other three sub-networks. Table 6.1 below re-introduces the features that indicate the consistency of the business sub-network.

Table 6.1 Indicators for consistency of the business sub-network

Business sub-network actors	General aims by sub-network	Features indicating consistency
a) industrial associations b) competitors c) customers d) suppliers e) consultancy firms f) incubators g) private non-profit organisations acting on behalf of the public interests	i) foster and support interactions among firms and between firms and customers ii) support for research funding applications iii) access to information on national and international markets iv) provision of facilities or knowledge for software development, training and workshops v) support the design of business plans and training on organisational matters vi) support software process improvement vii) incubation programmes	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Access to new sources of financing 5. Access to commercial information 6. Innovation co-operation

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

The Campinas business sub-network was not only the most frequently accessed by Campinas software firms, but also the sub-network with the highest consistency; this means that there was a high level of overlap between the reasons for creating a tie (e.g. ‘innovation cooperation’) and the aims of the business organisations with which ties were formed. The three business actors with the highest number of ties are: incubators, customers and other software firms.

The feature of the ties created with the three incubators reflected provision of financial support, that is, low infrastructure costs (e.g. office facilities, security, broadband access, fixed telephone line), a commercial address and the provision of business consultancy. In more than one case entrepreneurs of incubated firms said they could not had afforded the market price for the infrastructure offered by the incubator:

> when we [interviewed firm] set up our firm, we [interviewed firm] had recently graduated from IC [Unicamp undergraduate degree in computing science], and as new graduates we did not have the financial resources to pay for office space and other infrastructure. Without the incubator’s

> support we would have had to set up the firm in a room in my or my partner's house. It makes a big difference if prospective clients see a commercial address on your business card, it looks much more professional and reliable (Campinas fieldwork interview number 44).

Another feature of local firms' ties with incubators is business consultancy which is provided at subsidised cost. Consultancy focused mostly on start-up business plans and identification of market niches, that is, services related to commercial knowledge. According to some interviewees, Campinas local entrepreneurs who graduate in IT related degrees have no training in entrepreneurship,[238] they are technically skilled to resolve complex problems, and may come up with new ideas for new products or services. However, these young professionals have almost no commercial knowledge to develop their ideas further, and this is where the incubator's consultancy service plays a crucial role, as stated by an interviewee:

> the most common profile of [Campinas IT] incubated entrepreneurs is recent graduates. It is very common to finish university with good technical skills, and good ideas about how to exploit this scientific knowledge, but no idea about whether there is real demand for the innovation, or how to produce an executable business plan and implement it. This is why the consultancy offered by the incubator is so important, it provides the [incubated] start-up with a base of commercial knowledge to support its early years (Campinas fieldwork interview number 11).

This view was expressed by other from firms that initially were incubated, as follows:

> when we [interviewed firm] entered the pre-incubation programme we had no clue about how to deal with administrative issues, or how to write a business plan. We did not know where to start from, for instance, with regards to potential demands for our services. The consultancy provided by the incubator was crucial for us in both administrative and business related aspects. And it was affordable, because it is subsidised (Campinas fieldwork interview number 22).

and,

> the consultant asked questions that nobody else had asked us before, making us think about what we were doing, what had to be done if we wanted to succeed. We had been graduated for a few years, but the consultant still provided us with consultancy services (Campinas fieldwork interview number 44).

The features associated with the creation of ties between firms and their customers differed among firms; the three firms identified different features as promoting tie creation. For instance, only Firm 1 identified 'acquisition of knowledge and

[238] Campinas interviews number 3, 11, 15, 20, 22, 29, 35, and 44.

technology' as relevant for tie creation, which was unexpected since all three firms' ties with customers were related to developing customised software. Therefore, firms were expected to 'acquire knowledge' in the process because the development of customised software applications requires a close user-producer relationship and full understanding of customers' business and technologies. The development of new applications often demands that the firm acquire new knowledge to understand how to develop applications. This process enhances the firm's technical capabilities, and therefore its opportunities to develop new applications in the future.[239]

However, the other features promoting ties with customers were consistent. For instance, we identified 'innovation co-operation' and 'new sources of financing'. With regard to the former, most firms in the sample developed customised software for customers that requested it. Customers provide the information about their businesses and current software and the new software is an innovation for the creating firm.[240] The customer financed the software innovation, the customised software, in the case of the firm interviewed.

In addition to ties with incubators and customers, there are ties with other software firms, where we found the only inconsistency in the business sub-network. Inconsistency emerged only in the case of a tie between two software firms that developed complementary software. The tie was related to financial issues only, although it might have been expected to relate to 'access to new knowledge' and 'innovation co-operation' (which would have indicated consistency). Tie creation was driven by a requirement of the funding agency financing the development of the new software. There was inconsistency in relation to the items in the questionnaire chosen to demonstrate consistency.

We found one case of a tie among local software firms developing complementary software to obtain 'access to commercial information', showing consistency in the business sub-network. According to the interviewee, because the collaborating firm develops complementary knowledge, its marketing expertise is also complementary

---

[239] In the case of one firm 'acquisition of knowledge' was mentioned as a *result* of the tie created with the customer, however it did not motivate tie *creation*. According to the interviewee, the innovation resulted in the enhancement of the firm's capability with regard to the development of applications for new market niches. Previous to the innovation, the firm had mostly developed software for a specific market niche, which had limited its penetration of other markets (Campinas fieldwork interview number 42).

[240] Campinas fieldwork interview number 42.

and its knowledge in this particular issue provided the interviewed firm access to new markets.[241]

6.2.2 Consistency of the skills sub-network

The skills sub-network was the second most frequently accessed sub-network by the Campinas local software firms, and applied to all investigated innovation stages, as follows: i) 4 firms created 11 ties with 4 types of actors for commercialised innovations; ii) 4 firms created 5 ties with 2 types of actors for ongoing innovation, 1 firm created 2 ties; and iii) 1 firm created 3 ties with 1 type of actor for later abandoned innovations.[242] In all innovation stages universities were the most frequently accessed type of actor. Table 6.2 re-introduces the features that indicate consistency for the skills sub-network.

Table 6.2 Indicators for consistency of the skills sub-network

Skill sub-network actors	General aims by sub-network	Features indicating consistency
a) universities b) technical colleges c) continued education organisations d) research council e) research foundation	i) IT training in different levels, such as: undergraduate, Masters, Doctorate and Post-Doctorate and continued education ii) support new knowledge creation through basic or applied research funding programmes iii support new knowledge creation through funding programmes for development activities	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Innovation co-operation

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

There are three important findings from the examination of the skills sub-network. *Firstly*, none of the ties created by firms for the commercialised innovation stage with organisations belonging to this sub-network related to 'acquisition of knowledge'. This applies even to ties with eight university departments that were part of the ten skills organisations engaged in the network of innovators. The absence

[241] Campinas fieldwork interview number 35.
[242] Sub-network actors were identified a priori to the empirical data collection (Chapter 5).

of this feature was an unexpected result because educational organisations, and especially universities, produce new knowledge that potentially can be employed by the private sector. The features involved in tie creation included ‘access to open information sources’ and ‘innovation cooperation’ for this innovation stage.

‘Acquisition of knowledge’ was relevant for the creation of ties in the other two innovation stages, that is, ongoing and abandoned innovations; however the number of actors engaged in the network of innovators and the frequency of collaborations were low. Acquisition of knowledge was mentioned by one firm in the ongoing innovation stage and by another firm in the abandoned innovation stage. In the latter case, the reason for abandonment was that none of the three university departments contacted by the firm were willing to collaborate formally with the private sector:

> I [the firm] tried to create collaborations with three public university departments, and realised that although some faculty members are quite keen to collaborate with us [private sector], the higher divisions within their [university] departments did not approve the projects. These departments receive a lot of public finding, which seems to reduce the pressure on faculty members to seek finance from other sources, for instance the private sector. I think they [faculty members from public universities] are mainly interested in doing their academic research, which often excludes the private sector (Campinas fieldwork firm interview).[243]

The above extract suggests that the partial engagement of the Campinas local research university may be possibly related to over-funding from public sources of finance. This was partly corroborated by another firm that stated the following:

> the local university is not at all interested in collaborating with us [private firms], they are interested in following their own academic agenda. I will give you an example of how they are not interested in working with us [private firms]. About six months ago we [interviewed firm] needed training for our staff on a specific subject, and ideally it had to be offered by a university department. We had to go to ‘X’ [university department not disclosed for confidentiality reasons], which is not based locally because it was interested in providing this type of service. I guess that university is more open and more in need of extra funding [from the private sector] (Campinas fieldwork firm interview).

Another explanation for the scarcity of ties created by local firms with the local research university could be related to the type of expertise developed by the university (IC-Unicamp). For instance, one firm that is specialised in mobile

[243] As mentioned in Chapter 5, Section 5.5.2, interviewees are anonymous; for this reason in several interviews numbers are not disclosed but are replaced by the type of organisation from which data were collected.

technology stated that there are a few faculty members at the local research university who are experts in this knowledge area.[244]

Similarly, ‘acquisition of technology’ was expected to be relevant for tie creation with skills sub-network actors. However, only one firm that created formal ties with a university included the feature ‘acquisition of technology’ as relevant. The tie was related to the type of knowledge required by them and its availability from research universities, as follows:

> today we [interviewed firm] develop technology that is at the international scientific and technological frontier, and few university departments in the country develop knowledge and technologies related to the type of software we create. Their [university departments] technology is complementary to what we do, and collaborating with them gives us access to the technology we need at a much cheaper price than offered by the private sector, this is one of the main reasons why we created ties with these two [not disclosed to avoid their identification] university departments (Campinas fieldwork firm interview).

These findings suggest an absence of ties in the Campinas software network of innovators that would be important for the formation of local systems of innovations and its well functioning (see Bell and Pavitt, 1993 and Lastres and Cassiolato, 2001). It suggests also that the creation of ties between firms and skills sub-network actors is conditional on particular firm circumstances. As discussed in Chapter 2, inter-organisational links between private and public actors (and among themselves) that are related to technological and innovation activities support the formation of a system of innovation (Freeman, 1987; Lundvall, 1992a). Each organisation has specific aims and the well functioning of the system depends not only on the individual performance of organisations but also on their interaction with others (e.g. through the creation of formal inter-organisational ties). Therefore, these empirical findings have implications for government policy; policy formulation should take account of these particularities to be more effective (see Ergas, 1987, on technology policy, and Chapter 2 in this thesis). As discussed in Chapter 2, there is not a ‘one model fits all’ for policy promoting the formation of networks and their functioning.

The *second* notable finding in the ties created with the skills sub-network actors is that most of the universities engaged in the Campinas network of innovators are based outside the region (6 compared to 2 locally). There are two different interpretations: i) we might assume that Campinas firms are trying to create ties with

[244] Campinas fieldwork interview number 31.

universities that are more open to collaborations with the private sector (as discussed in Chapter 4 there is some evidence that the local research university is driven more by the creation of academic knowledge); or ii) that Campinas firms target universities with the most appropriate expertise, and these are not based in the Campinas region.[245] The empirical evidences shows that the ties created by one firm with three of the six university centres based outside the region were a requirement of the customer financing the innovation project. According to an interviewee:

> the main reason why we got involved with these universities is because they were included in the project by the client. We developed our part of the software using our internal knowledge and barely communicated with the other partners in the project, with the exception of the client, of course (Campinas fieldwork firm interview).

This shows an inconsistency in the Campinas skills sub-network, because it could be expected that the engagement of firms with these types of actors (e.g. research universities) would include knowledge or technology related matters as well as 'innovation cooperation' and 'access to open information source' (Table 6.2).

The *third* notable finding in the ties created with the skills sub-network actors relates to the ties created by firms with research councils (i.e. CNPq) and research foundations (i.e. FAPESP). We found that the ties created by Campinas local firms involved only 'access to new sources of financing' and not 'acquisition of knowledge' or 'acquisition of technology'. This is because these two organisations provide funding to firms to support the performance of basic and applied research, and development activities within the firm. These activities are directly related to the creation of new knowledge and technology by firms.[246] The absence of these two features indicated that there is inconsistency in the skills sub-network, and also that Campinas firms may be replacing private finance with public funding for their R&D activities. The preference of firms for public rather than private finance has been a constraint on the evolution of the Brazilian system of innovating (Corder, 2004: 121). This is not to say that public funding support is inadequate or should not be supporting the private sector. In fact, firms mentioned that public funding is very relevant for innovation projects if not already procured by the customer:

---

[245] This would provide evidence against general claims in the sectoral system of innovation approach with regard to the geographical localisation of knowledge, which is the overlap between the sectoral and regional system of innovation approaches.

[246] http://www.cnpq.br/english/cnpq/index.htm, accessed 14 February 2011. http://www.FAPESP.br/en/materia/6028/the-institution/FAPESP.htm, accessed 14 February 2011.

> I [the firm] am extremely grateful to 'x' [public funding organisation], if it was not for them we [the firm] would have had died by now [time of data collection], they provided non-refundable funding and believed in our project without expectations of marketable results. Their funding came at a crucial time, when the private market was down and we had only a few clients in our portfolio (Campinas fieldwork firm interview).

However, on more than one occasion interviewees mentioned that public funding is difficult to access. According to them, funding agencies expect firms that apply for research-oriented grants to submit proposals that are highly academically oriented:[247]

> the problem is that 'X' [public funding organisation] is very academically biased in the evaluation of research grants applied by firms. It is managed by academics, their referees are mostly academics, and they want to see in a firm research grant application what is familiar to them, i.e. an academic format. For example, recently one of the local micro firms received a grant from 'X' [public funding organisation] and all of their staff hold PhD degrees and what they [firm] do is very theoretical (Campinas fieldwork organisational interview).

According to firms, the academic bias in the assessment of grant applications has created a barrier to research funding from public organisations, because often firms do not have the required academic research skills. This deficiency can be overcome in the grant application process through the use of private consultancy services. The problem seems to be less for older or more research-oriented firms which have had time to develop capabilities to write grant applications that 'fit' the funding agencies' requirements. Also, some firms submit applications that are strongly research oriented:

> there was a time when we [interviewed firm] needed to hire consultants to write research grant proposals for us, but now we have learnt by trial and error how to do it, and can do it ourselves (Campinas fieldwork interview number 21).

And,

> we [interviewed firm] have some PhDs working in our firm innovation projects, I have done a few post-docs, and we [the firm] know exactly what we are doing, and better than anyone in the country. I can write research grant proposals very easily, I have done it before and can do it as a consultant for other firms (Campinas fieldwork firm interview).

[247] This issue is addressed by Pacheco (2007: 9), as follows: 'It prevails, including in the private sector, a concept of technology policy that is similar to the support for academic research. The supporting mechanisms to the private initiatives are shaped from experiences with universities, such as the employment of individual support and scholarships as incentive mechanisms for the technological development of the private sector'. (my translation)

The empirical evidence suggests that some of the reason for the absence of ties between firms with skills sub-network actors may be related to the perceptions of funding organisations with regards to the research activities performed by the private sector, and not the absence of supporting organisations as found in regional systems of innovations studies (see e.g. Chaminade and Vang, 2008). According to the firms interviewed, in addition to research funders expecting academically oriented research grant proposals that require specific skills and capabilities which they often lack, the timing of research grants proposals assessment is not synchronised with the pace of innovation in the software industry. This suggests that public funding organisations that aim to support local firms are suffering from path rigidity, which is unlikely to be changed in the short-term, because changing paths is costly and is a gradual long-term process. Also, historically, Brazilian public organisations suffer from institutional rigidity generally (see Pacheco and Corder, 2009, and Chapter 3 in this thesis).

If firms depend upon public research funding to innovate, they may either miss the opportunity to conclude innovation projects, or assume the costs of the innovation project which may in the future be financed by the public funding. This may jeopardise the success of the innovation project because firms sometimes lack the financial resources to perform all the stages required to complete the innovation project on time without external support. In addition, if firms decide to use internal financial resources for their innovation projects, and at some future stage are granted funding for activities already under development, they may be forced to 'make up' the figures and adjust the timing of the research project so that the final research grant report complies with the funding organisation's requirements.[248] New research funding is not released by the public funding organisations until previous research grant reports are revised and approved, hence approval of final research reports is considered crucial for future funding applications.

6.2.3 Consistency of the technology sub-network

The technology sub-network was the third sub-network most frequently accessed by the Campinas local software firms, for all innovation stages investigated.[249] Three

[248] Campinas fieldwork firm interview.
[249] The identification of networks actors partially derives from a priori identification of the organisations that are part (or are meant to be part) of the network (Chapter 5).

firms created three ties with three different technology sub-network actors, three different R&D organisations. Table 6.3 re-introduces the features that indicate consistency for the technology sub-network.

Table 6.3 Indicators for consistency of the technology sub-network

Technology sub-network actors	General aims by sub-network	Features indicating consistency
a) research organisations b) development organisations	i) perform basic or applied research for, among others, the commercialisation by the private sector ii) development activities for, among others, the commercialisation by the private sector	1. Acquisition of knowledge 2. Acquisition of technology 3. Innovation co-operation

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

There are three remarks about the ties created with technology sub-network actors. First, the features of ties created in the commercialised and ongoing innovation stages involved in 'innovation cooperation', which suggests that the sub-network is consistent. Second, the absence of 'acquisition of knowledge' and 'acquisition of technology' was an unexpected result. This is because according to the systems of innovation approach, in which network of innovators play a crucial role in supporting the creation of important links among organisations involved with innovation activities, it is expected that ties between innovative firms and R&D organisations are driven by the willingness of firms to acquire new knowledge and technology that complements internal knowledge (Lundvall, 1992b).

In addition, in the abandoned-innovation stage, the features involved in tie creation, 'access to new sources of financing' and 'access to commercial information', suggest inconsistency in this sub-network. According to the interviewee, the tie with the local R&D organisation was related to co-application for public funding:

> we had one abandoned innovation project during this period [2006-2009] which had collaboration from 'x' [local R&D centre], we tried to get public funding for the project but failed. So, as we did not get the funding, the innovation project was abandoned, and we have not been in contact with them [local R&D centre] since (Campinas fieldwork firm interview).

The extract above suggests that tie creation based on short-term opportunities and dependent on subsidies are more easily broken, which corroborates the evidence from studies on dyadic ties (see Chapter 2, Section 2.4.1).

In the commercialised innovation stage, we found that one of the two R&D organisations that had ties with local firms is based in the Northeast region, that is, outside the Campinas region. Although the R&D organisation is well known and has an excellent reputation in the Brazilian IT industry, which justified the features 'access to open information' and 'innovation cooperation' for the tie creation, two other things were important:

> they [R&D organisation] are very good in what they do and we benefited from the Informatics Law in collaborating with them, which was a very important aspect of the collaboration. And also we know someone who is trustworthy and has worked there [R&D organisation], which was a plus in the initial contact and success of the project (Campinas fieldwork firm interview).

This empirical evidence suggests consistency of the technology sub-network. However, the absence of 'acquisition of knowledge' and 'acquisition of technology' for ties with the R&D organisation, which instead were influenced by personal and financial issues, suggests partial inconsistency of the technology sub-network. In addition, the above extract confirms findings from other studies that personal relationships play an important role in inter-organisational ties (Chapter 2). It suggests also that geographical proximity is not always crucial for ties.[250]

6.2.4 Consistency of the financial sub-network

The number and frequency of ties created by firms with the financial sub-network were the lowest among the four sub-networks investigated. Table 6.4 re-introduces the features that indicate consistency for the financial sub-network.

[250] E.g., see Boschma (2005) for a broad discussion on proximity.

Table 6.4 Indicators for consistency of the financial sub-network

Financial sub-network actor	General aims by sub-network	Features indicating consistency
a) private and public banking organisations b) public funding organisations c) venture capitalists d) government authorities	i) grants or loans for firm-level basic or applied research and development activities ii) venture capital for start-ups iii) tax incentives for firm-level innovation activities iv) creation of technological parks or incubation programmes	1. Acquisition of knowledge 2. Acquisition of technology 3. Access to new sources of financing

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

A few Campinas firms created ties with only one public funding agency, the Brazilian Innovation Agency (FINEP), which suggests that this sub-network has virtually no connections with local firms. This is corroborated by two firms' innovation projects for the ongoing and abandoned innovation stages that were put on hold until FINEP's grant applications were awarded. Both firms stated that the projects depended upon FINEP financing, and in the case of non-award were abandoned.[251]

The empirical evidence on the features of ties created with FINEP indicated that the financial sub-network is partly consistent. All five firms that created ties with FINEP (i.e. both established or 'on hold' ties) indicated that they were motivated by 'access to new sources of financing', which is consistent with expectations. However, FINEP's mission is to support innovation in firms (among others) and only one firm in the sample said the tie was related to 'innovation cooperation', 'acquisition of knowledge' and 'acquisition of technology', all crucial for innovation. This is evidence of some level of inconsistency in the financial sub-network.

6.2.5 Summary

Investigation of the consistency of the four sub-networks provides evidence of for the following. Firstly, most Campinas software firms perform innovation without

[251] Campinas fieldwork firm interview.

external ties for knowledge and technology acquisition; knowledge for the development of innovation is mostly in-house. This is confirmed by the low engagement of the skills and technology sub-networks with ties in these sub-networks rarely related to ‘acquisition of knowledge and technology’ and driven mostly by ‘financial issues’.

Secondly, although the business sub-network demonstrates greater consistency between the features of ties identified and expected, the relevant actors in this sub-network that might be expected to provide new knowledge to firms – customers and other software firms – did not figure prominently. Also, any ties with them were not often related to ‘acquisition of knowledge and technology’.

Analysis of the consistency of the four sub-networks is complemented by an investigation of the motivation for tie creation among firms, and between firms and other network actors, in Section 6.3.

6.3 Network Relations for Innovating and Non-Innovating Firms: Campinas

This section investigates how many and which firms performed innovation, either alone or in collaboration with other network actors, the tightness (motivation and frequency) of the ties among Campinas software firms and between firms and other organisations, and which firms and network actors are functioning (or are more likely to function) as bridges within the network of innovators. We investigate each of these three issues for each innovation stage analysed in the thesis, that is, commercialised innovation (Section 6.3.1), ongoing innovation (Section 6.3.2) and abandoned innovation (Section 6.3.3). The representation of the network of innovators for each innovation stage supports the examination of the empirical evidence.

6.3.1 Network of innovators for commercialized innovations in the period 2006-2009

The investigation in this section provides evidence on the three issues referred to above. Figure 6.1 supports the visualisation of the network of innovators for the commercialised innovation stage during the period April 2006-April 2009. It depicts the actors engaged in the network of innovators and the cluster of nodes to which they belong, and also which actors are functioning as bridges within the network of innovators. It shows whether ties are tightly or loosely-connected.[252]

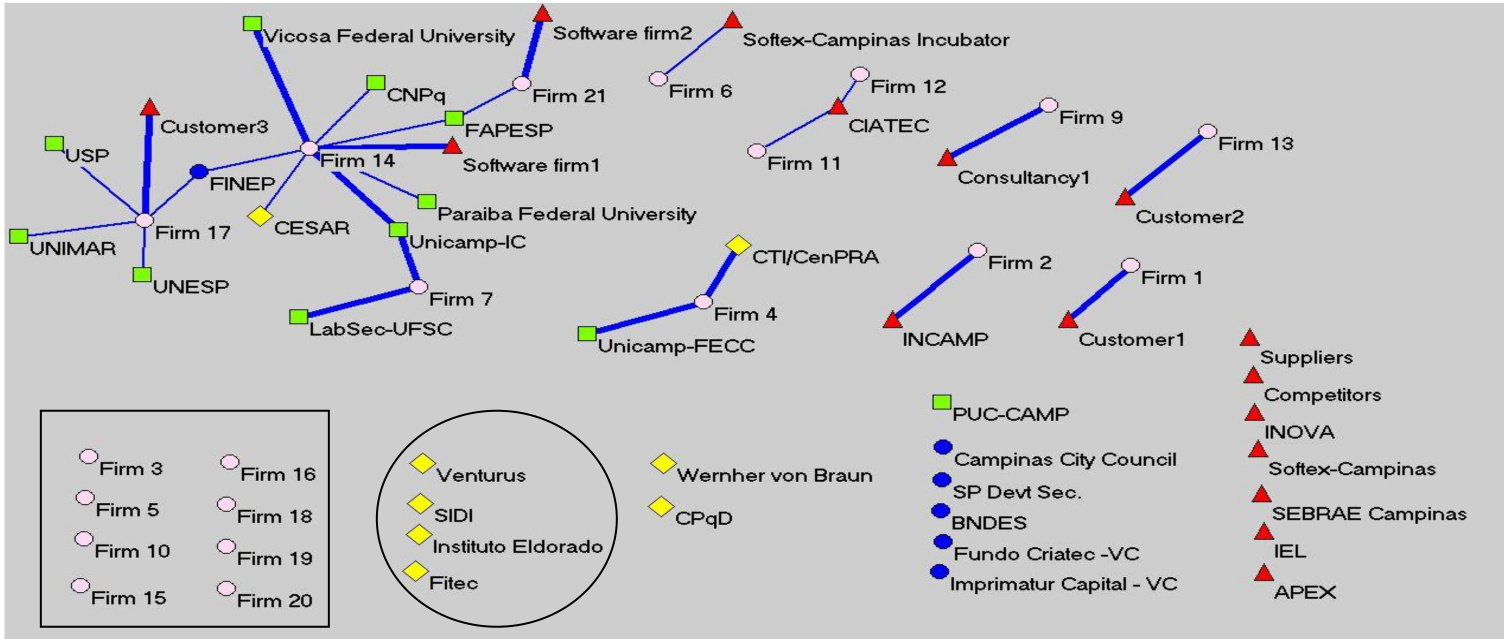
Innovative firms and inter-organisational ties

The examination of how many and which firms innovated during the period 2006-2009 and whether they created external ties to support their innovation, shows that almost all Campinas firms innovated during that period.[253] This finding was expected because it is intrinsic to the software industry that most software development involves innovation (Brooks Jr., 1995; Grimaldi and Torrisi, 2001; Rousseva, 2008; Steinmueller, 1996; Torrisi, 1998). Forty percent of interviewed firms did not create an external tie to support their innovation activities, but innovated alone. Only four firms engaged in the main cluster of nodes, five firms created binary ties and three firms created triad ties.

[252] As discussed in Chapter 5 Section 5.5.2, it is important to highlight that this representation is not intended to reproduce the structure of the network as analysed in other studies employing social network analysis methodology. Rather, it is a representation indicating patterns of ties among network actors within a particular institutional setting.

[253] The exception is one firm that was incubated and had not commercialised the innovation at the time of data collection.

Figure 6.1 The Campinas software network of innovators: commercialized innovations during 2006-2009



Legend:
● Firms
♦ Technology sub-network
■ Skills sub-network
▲ Business sub-network
● Financial sub-network
Tight connections =
Loose connections =
□= Firms that did not create external ties to support their commercialised innovation.
○= Autonomous private non-profit R&D organisations originally set up by multinationals that are disengaged from the network of innovators.
Note: Firm 8 did not commercialise innovations during the period under analysis.
Source: own elaboration based on fieldwork data collection.

The ties outside from the main cluster were mostly with incubators. This may be important because once firms become more mature they tend not to refer to incubators as formal collaborators, even if an innovation was developed during the incubation period. For instance, three firms matured after 2006 but did not refer to incubators as formal collaborators for the commercialised innovation.[254] However, this does not mean that firms did not acknowledge the importance of incubators. As already discussed, they found their support especially crucial for setting up their business, but dropped them as collaborators later. The above discussion leads to the conclusion that the Campinas network of innovators is fragmented rather than well-knit. This network characteristic suggests that there is low level diffusion of information in the network of innovators, which might have implications for network effectiveness (as discussed by Burt, 1992). This issue is addressed later in this section.

Tightness of inter-organisational ties

Although the structure of the network is not well-knit, the majority of ties are tightly-connected as opposed to loosely-connected (where tightness of ties is determined by their motivation and frequency). This finding indicates ties were created for reasons of trust, collective identity, personal relationships, and knowledge availability and accessibility. Also, in most cases geographical proximity supported the creation of tightly-connected ties.[255] These were expected findings because direct ties are frequently associated with tight connections. In addition, as Asheim and Gertler (2004) show, local contexts support trust building among actors (i.e. corroborating Callon's (1999) claim that economic actors rarely take decisions based on arm's length relationships); and networks support the breeding of trustworthy relationships (Giuliani, 2010). Conversely, we found that there were direct loosely-connected ties, which were motivated by opportunities, financial issues or requirements for ties. Hence, the investigation of loosely-connected ties became relevant.

[254] Campinas fieldwork firm interviews.
[255] However, we found one firm had a tightly-connected tie with a collaborator outside the region (university department) and one of the motivations for its creation was collective identity. The firm performs in a very specific market niche (is one of the few to develop the software application in the country), and there are only a few university departments that create knowledge related to the software developed by the firm. Therefore, community involved in innovations in that area is small; when professionals get to know one another they feel part of the community. Campinas fieldwork firm interview.

We find that loosely-connected ties occur more frequently among network actors in the skills and technology sub-networks and generally involved two of the firms in the main cluster of nodes, Firms 14 and 17. The existence of loosely-connected ties was an unexpected result, because ties created with organisations involved in the creation of new knowledge or technology (such as universities and R&D organisations), are supposedly motivated by trust, collective identity, knowledge availability and accessibility. These motivations were not the appropriate for some of the ties created by Firms 14 and 17, as explained below.

The motivations that justified the loosely connection of Firm 14 were opportunity and cost. Cost related to ties created with funding organisations. Opportunity applied to ties with a university department and a R&D organisation, both outside the region. These motivations are related to the inconsistencies of the skills and technology sub-networks (discussed in Section 6.2). Although the inter-regional ties were loosely-connected, it is important to highlight that actors engaged in the Campinas network of innovators are able to and do access other network actors outside their region. This might be relevant for avoiding the network lock-in and sclerosis, discussed by Grabher (1993).

Although we classify Firm 17 as having loosely-connected ties, we need to look at the motives for these ties with three university departments. They were based on a customer requirement and as part of the contract terms (as discussed in Section 6.2). Therefore, we can assume that they might not have been formed without such a requirement, which makes them rather ‘ephemeral’.

For ties created with the technology sub-network, we find that although there are six private non-profit R&D organisations and one laboratory in the region, only Firm 4 engaged with one of the R&D organisations, CTI/CenPRA. This was a tightly-connected tie. However, the interviewee explained the motivations for its creation, as follows:

> I always engage with FEEC-Unicamp first. I am doing my Masters there and have a strong and trustworthy relationship with my supervisor, we [firm and supervisor] have collaborated before. Once we [firm and supervisor] have a common project, then we involve CTI/CenPRA. This is because my supervisor has a strong relationship with some of their [CTI/CenPRA] researchers, who are also students at FEEC-Unicamp. Some of them are my classmates. Thus, the engagement of CTI/CenPRA occurs as a consequence,

> and it is always bridged by my supervisor (Campinas fieldwork firm interview).[256]

Although only CTI/CenPRA has ties to a local firm, some interviewees mentioned cases where their firms had local R&D organisations as customers (although not during the period analysed in this thesis), for work outsourced as part of their innovation activities. This suggests a hierarchical relationship between Campinas software firms and local R&D organisations, meaning that these organisations are able to outsource development activities to firms, but local firms may only be able to access and employ knowledge created by the centres for their own innovation activities, when the R&D organisations are their customers.[257] However, the innovation projects developed by the firms sampled in this research did not involve R&D organisation participation as a customer. Section 6.2 shows that ties created with customers rarely involve features related to the acquisition of knowledge and technology.[258]

The loosely connections between local firms and FAPESP and CNPq corroborate the inconsistency of the skills sub-network related to public research funding organisations, discussed in Section 6.2.2. In addition, these organisations have a small number of ties with innovative firms engaged in the network of innovators. There are two reasons for this. Firstly, Campinas firms complained about frequent delays on the part of the funding organisation in the proposal assessment stage, which tended to hamper innovation activities whose performance depended on the funding organisation.[259] This is important because most firms in the region are micro or small firms,[260] with little capacity to finance new developments using only internal capital. Both local firms and funding organisations acknowledged that funding support to the IT industry generally (not just software firms) is not synchronised with the speed of innovation in this industry. Funding organisations

---

[256] This quote confirms Callon's (1999) claims that network actors are not guided by arm's length decision making.

[257] Campinas interviews numbers 2, 5, and 39.

[258] As discussed in Chapters 3 and 4, most of the other R&D organisations (not formally connected to a local firm) were set up by multinational firms to benefit from the Informatics Law. E.g.Ericsson founded Venturus, Samsung founded SIDI, Motorola founded Instituto Eldorado, and Lucent Technologies found Fitec (therefore CPqD and Wernher von Braun are exceptions). These R&D organisations were set up as autarchies mainly to support their founders' development activities (Ritz, 2008; Stefanuto, 2004)

[259] Campinas interviews numbers 21, 27, 31, 35, 36, and 42.

[260] This includes firms not part of the sample of interviewed firms; see Chapter 4 above for the profile of local firms.

tend to replicate funding mechanisms used to support traditional sectors, whose needs are different from those of high-technology and technology-based firms. As already mentioned, this finding points to institutional rigidity in the public funding organisations.

Secondly, there seems to be a bias among funding organisations towards academically oriented research and research proposals for grants. As discussed above, this sometimes required firms to adopt an academic type format for their business research proposals, which was time consuming and because they often did not have the required expertise, incurred extra costs in the form of consultancy advice.

Bridging organisations within the network of innovators

The third issue is which organisations may become or are already functioning as bridges within the network of innovators. The importance of bridging organisations relates to the argument that the main advantages of participation in a network of innovators include the possibility of learning-by-interacting, and benefitting from network externalities (Shapiro and Varian, 1999). Therefore, bridging organisations prospectively support the creation of ties among firms, and between firms and other network actors. The network of innovators depicted in Figure 6.1 (p. 176 above) suggests that there are some organisations with indirect ties to firms within the main cluster of nodes. The functioning of these organisations requires special consideration.

The first consideration is that there are a few bridging organisations (as opposed to firms) in the main cluster of nodes (which reduces the diffusion of information), and they are part of the skills (FAPESP and IC-Unicamp) and financial (FINEP) sub-networks. The second consideration is that close investigation of the aims of FAPESP and FINEP, together with empirical evidence from local firms,[261] indicates a low likelihood of these two organisations fostering the creation of ties among firms indirectly connected to them. This is mainly because assessment of proposals for grants is done ‘blind’ and there is no personal contact between firms and grant application reviewers. This applies also to contacts between firms and administrative staff involved in project implementation. This seems to apply especially to FAPESP:

[261] Fieldwork interviews numbers 16, 23 and 46.

> our [firm's] relationship with FAPESP is very distant, we [firm] do not know who is dealing with our grant, we always talk to the 'system', there is a generic email that we communicate with. We believe that it is set up in such way to avoid favouritisms in future applications. With FINEP is different, there a technical assistant responsible for our grant, we know who this person is, and it seems to work better, there is less bureaucracy, we talk directly to the person who can help us solve problems (Campinas fieldwork firm interview).

However, it is neither FINEP's nor FAPESP's job to connect firms that have already received grants from the organisation. Nevertheless, both organisations act as bridges by providing funds through special calls or programmes that require the creation of ties among firms or between firms and actors which may belong to the skills and technology sub-networks (this conforms to the 'thematic funding' technology policy channel discussed in Chapter 2, Section 2.2.2).

IC-Unicamp (the Computing Science Institute) also plays a bridging role. Figure 6.1 (p. 176 above) shows that IC-Unicamp has formal ties with two firms. Empirical evidence shows that IC-Unicamp could and is likely to function as a bridge between these two firms, and other firms within the network of innovators. However, this role is not likely to be at the organisational level, and relates to faculty member's individual initiatives and relationships. Thus, this bridging role may be limited by the low number of IC-Unicamp faculty members who are interested in creating ties with the private sector.[262] Although, faculty members play an important role as some sort of 'gatekeepers' of the IC-Unicamp community (which includes former undergraduate and post-graduate students), faculty members are knowledgeable and able to share valuable information with local firms. In that sense, IC-Unicamp functions as a bridging organisation in the Campinas network of innovators.

We found also that over its history IC-Unicamp has created a community of former students (alumni). These individuals are part of an informal network in which 'collective identity' is relevant for the sharing of information on new markets opportunities and firm strategies (see Pavitt, 1987, on communities of common knowledge). The virtual network 'Unicamp Ventures' and the creation of the ActMinds export consortium (discussed in Chapter 4, Section 4.2) are two examples of IC-Unicamp acting as an informal bridging organisation in the region. According to Marinho and Simis (2007), and fieldwork interviews, there is a high level of trust

[262] Campinas interviews numbers 1, 2, 11, 23, 26, 35, 42 and 44.

among ActMinds firms, and the fact that many eventual entrepreneurs studied at IC-Unicamp is important for trust building among firms, and for the success of the consortium.[263]

A final comment on bridging organisations not depicted in Figure 6.1 (p. 176 above), relates to the role of local incubators. Although none of the three local incubators is tied to the main cluster of nodes, they function as bridges for tie creation between incubated and 'graduate' firms. This is because the managers of incubators are very knowledgeable about both groups of firms, and are likely to suggest contacts for collaboration (either formal or informal). This applied to ongoing innovation, which is analysed in Section 6.3.2.

6.3.2 Network of innovators for ongoing innovations in the period 2006-2009

This section investigates the Campinas software network of innovators in the ongoing innovation stage during 2006-2009. It examines: i) how many and which firms performed innovation activities, either alone or in collaboration with other network actors; ii) the tightness of the ties among Campinas software firms and between firms and other organisations; and iii) which firms and network actors are functioning (or are likely to function) as bridges within the network of innovators.

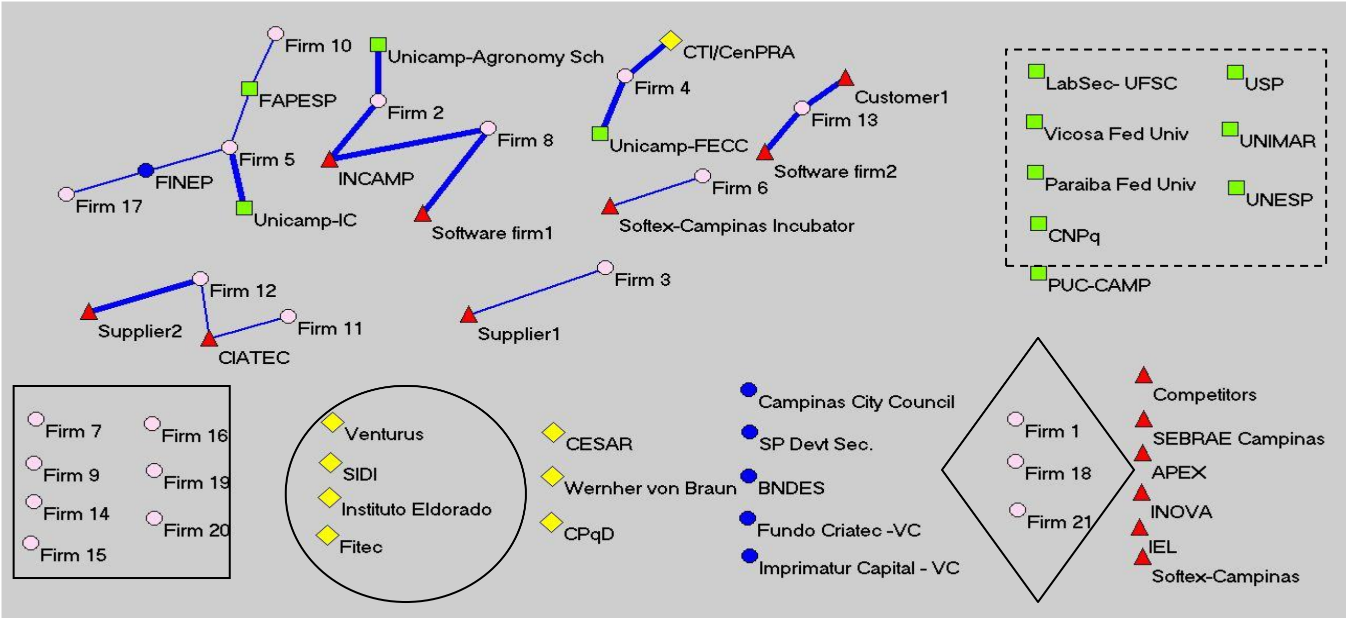
Innovative firms and inter-organisational ties

The empirical evidence on ongoing innovation by Campinas software firms shows that the network of innovators is different from that depicted in Figure 6.1 (p. 176 above). There are fewer firms (18) involved in innovation in the ongoing stage compared to the commercialised stage analysed in the previous section (20 firms). Firms 1, 18 and 21 commercialised their innovation near to the time of data collection (May/June 2009) and were not involved in a new innovation at the time of the interviews; Firm 8 was not involved in commercialised innovation but was developing an ongoing innovative service. Figure 6.2 supports the visualisation of the network of innovators for the ongoing innovation stage during the period April 2006-April 2009.

---

[263] Campinas fieldwork organisational interview. For detailed information on ActMinds creation see Marinho and Simis (2007).

Figure 6.2 The Campinas software network of innovators: ongoing innovations during 2006-2009



Legend:
- Firms
- Technology sub-network
- Skills sub-network
- Business sub-network
- Financial sub-network

Tight connections =

Loose connections =

□= Firms that did not create external ties to support their ongoing innovation.

○= Autonomous private non-profit R&D organisations originally set up by multinationals that are disengaged from the network of innovators.

◊ = Firms that did not have ongoing innovations at the time of data collection.

[ ] = Actors in which firms broke ties from the commercialised innovation stage.

Source: own elaboration based on fieldwork data collection.

The number of firms with external ties to support their ongoing innovation was almost the same as in the commercialised innovation stage (Section 6.3.1). However, for the ongoing innovation stage there is no core cluster of nodes, but instead several small clusters or isolated dyadic ties. This suggests that the level of diffusion of information within the network of innovators is low (i.e., similar to the finding for commercialised innovation - Figure 6.1). This low level of diffusion might have negative implications for the effectiveness of the network (Burt, 1992) and may suggest the absence of links within the network (discussed in Bell and Pavitt, 1993, Lastres and Cassiolato, 2001, Chaminade and Vang, 2008, Padilla-Pérez *et al.*, 2009 and Lundvall *et al.*, 2009 with regards to the systems of innovation in developing countries).

Tightness of inter-organisational ties

The structure of the network of innovators shows that many of the ties created for the commercialised innovations stage do not exist in the ongoing innovation stage, and the network actors disappear from the network. Most of these were loosely-connected ties with skills sub-network actors, such as the Paraiba Federal University, USP, Unimar, Unesp and CNPq, and also CESAR, which is part of the technology sub-network. All of these actors are outside the Campinas region. The breaking down of these ties in the ongoing of innovation stage indicates that geographical proximity may affect the strength of these ties and their maintenance over time. It may indicate also that when an innovation gets to market, the partners may re-assess what they are gaining from a link and abandon it if it is seen as no longer useful. It is consistent also with the expectation that loosely-connected ties are more vulnerable to breakage than tightly-connected ties.

However, two actors outside the region were involved in tightly-connected ties in the commercialised stage and were dropped in the ongoing stage. In this case, geographical distance was not an impediment to the creation of tightly-connected ties. Despite geographical distance, both firms collaborated with these actors which were involved in research very close to the expertise of the firm, as stated by one of the interviewees:

> we [firm] have collaborations with ‘x’ [research university department] because they perform research very close to what we do, we [firm] feel that we [firm and research university department] belong to the same community especially because there are not many actors in the country that do what we

> do. The reason why we are not collaborating with them at the moment is because there is no ongoing project that requires collaboration, but in the future we would not hesitate to create ties with them (Campinas fieldwork firm interview).

Secondly, although the ties were tightly-connected, they were not maintained for the ongoing innovation stage, which suggests that the geographical distance could have become an obstacle for the maintenance of the ties (but not for tie creation). There were four firms (3, 5, 8 and 10) that had created ties during the ongoing innovation stage rather than the commercialised stage. The tightness of these ties varied, but the patterns were similar to the commercialised stage of loosely-connected ties with FINEP and FAPESP and tightly-connected ties with IC-Unicamp.

A novelty in this stage was the appearance of suppliers as collaborators. However, their low frequency (ties by two firms) and the different tightness of the ties did not allow the identification of a pattern of ties with suppliers. There were not ties with customers in this stage, which is somewhat surprising because customers are assumed to be important for small and micro firms software developers for learning-by-interacting. However, ties created during a period when revenues are accruing come under pressure because of different expectations about the benefits that should flow from the interaction.

We find that most ties were tightly-connected, and some firms with tightly-connected ties had maintained their ties over time. Again, this was expected for the reasons discussed in Section 6.3.1. In the case of loosely-connected ties these were mostly with FINEP and FAPESP and were motivated by cost and opportunity, that is, they replicated the patterns found for commercialised innovations (discussed in Section 6.3.1) and corroborate the inconsistency with expectations for the technology and financial sub-networks discussed in Section 6.2.3 and Section 6.2.4.

Bridging organisations within the network of innovators

Bridging organisations, showed the same pattern as discussed in Section 6.3.1. FAPESP, FINEP and IC-Unicamp functioned very similarly in the ongoing innovation stage compared to the commercialised innovation stage. However, there are two differences. Firstly, Incamp (Unicamp incubator) functions as a bridge between innovators, in this case geographical proximity was important for the creation of ties:

> the incubator has put us [interviewed firm and collaborating firm] in contact, they [incubator] are aware of what each incubated firm does, and from this referral we [interviewed firm and collaborating firm] concluded that could use the complementary expertise developed by our firms to work on a new product. The fact that we are incubated supported the building of trust for the collaboration, and because we share the same facilities the communication is very easy (Campinas fieldwork firm interview).

Incamp also functions indirectly as a bridge, as stated by the interviewee:

> the incubator supports us [incubated firms] with several issues, but maybe more importantly they [incubator] support us by facilitating access to Unicamp faculty members. I have contacted some faculty members to explore the possibility of collaborations and felt that because the firm is incubated at Incamp they [faculty members] are more open to talk to us [interviewed firm]. They [faculty members] may not be willing to collaborate, but at least they will agree to talk. I think they feel that we belong to the same community, because we are located on the campus. Now we [firm] are collaborating with a Unicamp faculty member (Campinas fieldwork firm interview).

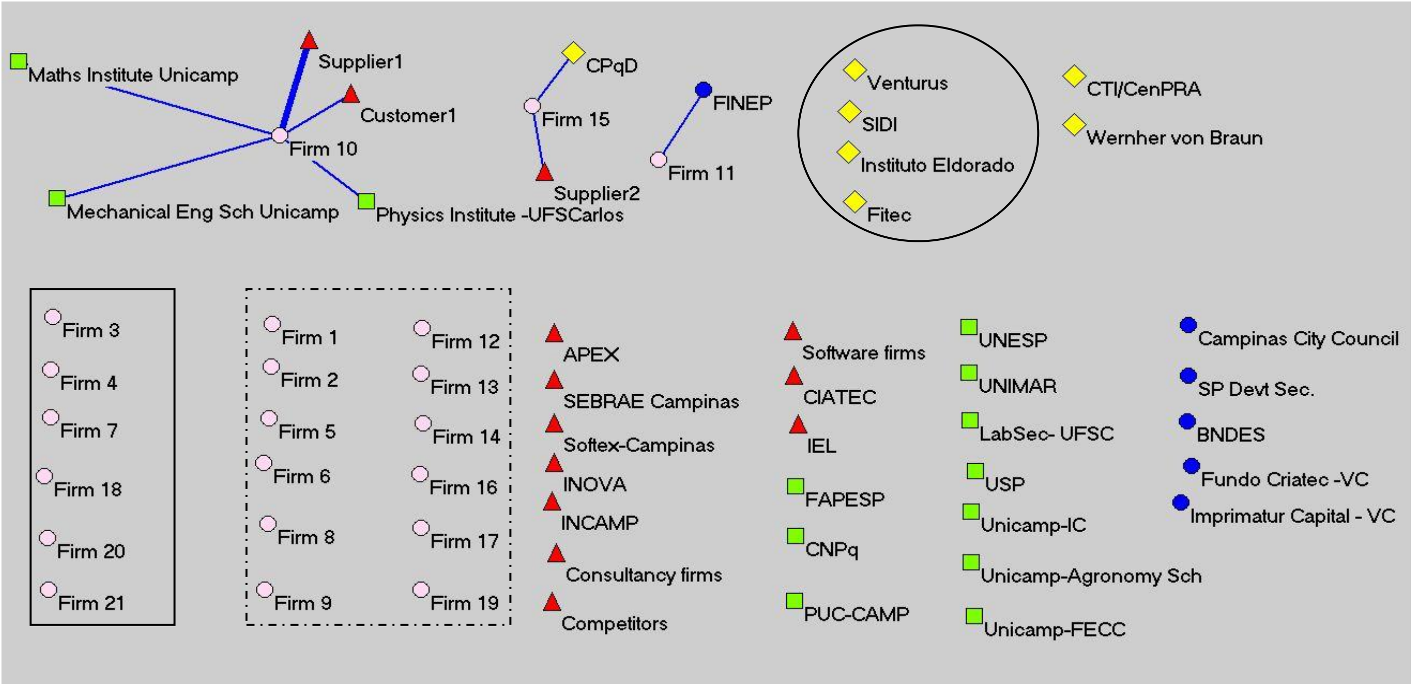
Figure 6.2 (p. 183 above) does not capture the indirect role played by Incamp in bridging between network actors. This shows that close examination is required for a full understanding of how networks of innovators are structured and how they function, as discussed in Chapter 5, Section 5.4.1.

This section shows that the number of firms that commercialised innovations during the period 2006-2009 did not change considerably in the ongoing innovation stage and neither did the patterns related to the tightness of ties. However, during the abandoned innovation stage, there were several changes (see Section 6.3.3).

6.3.3 Network of innovators in abandoned innovation stage in the period 2006-2009

The empirical findings show that the majority of Campinas software firms did not abandon any innovation activities during the period 2006-2009 and also among firms that did most had no external ties to support their innovation. In this case, the over fragmented structure of the network compared to the other two investigated innovation stages (i.e. commercialised and ongoing innovation stages) suggests both an ineffective network and an absence of links to support firms' innovation activities. Figure 6.3 represents the structure of the network of innovators in the abandoned innovation stage.

Figure 6.3 The Campinas software network of innovators: abandoned innovations during 2006-2009



Legend:
- Firms
- Technology sub-network
- Skills sub-network
- Business sub-network
- Financial sub-network

Tight connections =

Loose connections =

□= Firms that did not create external ties to support their abandoned innovation.

○= Autonomous private non-profit R&D organisations originally set up by multinationals that are disengaged from the network of innovators.

= Firms that did not abandon innovations for the analysed period.

Source: own elaboration based on fieldwork data collection.

We find that Firm 15 created external ties to support their innovation for the first time, however, they were loosely-connected ties. The innovation performance of Firm 15 depended on successful application for public funding, which did not happen and explains why the innovation activity was abandoned and the ties broken.

We see that the majority of direct ties were loosely-connected. This result is unexpected because in the two innovation stages analysed previously (commercialised and ongoing) most direct ties were tightly-connected. The higher frequency of loosely-connected ties in abandoned innovations indicates that such ties are more vulnerable to breaking, even in the cases of ties created with skills and technology sub-network actors (as discussed above, ties with skills and technology sub-network actors are expected to relate to tightly-connected ties).

Figure 6.3 shows that there were few bridging organisations involved in the abandoned innovation stage and none was connected local firms: they were isolated ties.

6.3.4 Summary

This section investigated three characteristics of the Campinas software network of innovators: i) whether local software firms created external ties to support their innovation activities, in the three stages analysed, that is, commercialised, ongoing and abandoned innovations, in the period 2006-2009; ii) the tightness of dyadic ties created by firms to support their innovation activities; and iii) which organisations functioned as bridges in the network of innovators. Analysis of the three stages demonstrates that there is a pattern in the Campinas local software network of innovators regardless of the innovation stages: i) most local firms tend to create external ties for innovation; although the number of collaborating actors is small they are in the majority in the business sub-network; ii) the network is more likely to be composed of fragmented clusters of nodes rather than being well-knit; iii) most direct ties are tightly-connected ties (with the exception of the abandoned innovation stage); iv) although there are bridging organisations in the commercialised and ongoing innovation stages, only IC-Unicamp and incubators are more likely to foster the creation of ties among local firms.

Analysis of the dyadic ties created by firms discussed in this section and of the consistency of sub-networks (Section 6.2) provides evidence on the governance of the Campinas network of innovators. The *structural* and *relational* embeddedness of this network is related to the institutional context in which local firms innovated during the period under analysis, June 2006-June 2009. Section 6.4 investigates the innovation activities of Campinas local firms, and discusses how network governance influenced innovation performance in the region.

6.4 Campinas software network: innovation at firm level

This section investigates firm-level software innovation in the three stages analysed. The aim is to identify which firms are innovating, whether they are connected or disconnected to the main cluster of nodes, and how many and what is the degree of novelty (firm or market level) of their innovations. Section 6.4.1 investigates commercialised innovations in the period 2006-2009; Section 6.4.2 investigates the ongoing innovations at the time of data collection. Section 6.4.3 examines innovations abandoned during this period.

6.4.1 Commercialized innovations

This section investigates commercialised innovations by Campinas software firms in 2006-2009. The empirical findings show that more commercialised innovations relate to software services (17 firms) than software products (6 firms). In software products, two firms (2 and 7) stand out for the number of their innovations. Table 6.5 summarises the innovation performance of local firms that commercialised software products.

Firm 2 commercialised innovations that were new to the firm, that is, there are similar software products in the market (both national and international). This firm had external ties with the Incamp incubator (see Section 6.3). Firm 7 commercialised more product innovations, all of which were new to the national market and three of which were new to the world (the international market). There were no competitors to Firm 7's innovations on the national market. However, none of these innovations had been exported at the time of data collection. This firm has external ties with two skill sub-network actors (university departments) that supported two of their commercialised innovations. There are a few reasons for this firm's outstanding performance compared to other local firms that commercialised software products.

Table 6.5 New software *products* commercialized by Campinas software firms during the period June 2006- June 2009

	Total number of innovations	Innovation new to firm	Innovation new to national market	Innovation new to international market
Firm2	6	6	**0**	**0**
Firm5	2	2	1	**0**
Firm7	10+	10+	10+	3
Firm13	3	3	1	**0**
Firm14	3	3	2	**0**
Firm16	2	2	1	**0**
Total	26	26	15	3

Source: own elaboration based on fieldwork data collection.

Firstly, this firm is an informal ‘spin-off’ from IC-Unicamp:

> we [firm’s entrepreneurs] were studying at IC and worked in a research project. The project was very successful and we realised that there was a market opportunity for a new product, the customer that financed the project with IC decided to develop this product with us [the firm]. There was no competitor in Brazil that could produce this new product, so we [firm and customer] decided to have a go and it has been a successful partnership (Campinas fieldwork firm interview).

Second, Firm 7 maintained a strong ongoing relationship with the IC research group through formal training of its employees (Masters and Doctoral training), and a relationship based on trust. Relationship based on human resources training is not captured by the representation of the networks of innovators in Figure 6.1 (p. 176 above). As discussed in Section 6.3.1, this endorses the need for very close examination to explain the functioning of networks of innovators and firms’ innovativeness. Firm 7 also had the highest number of new software services commercialised during the period 2006-2009, both new to the firm and also to the national and international markets. However, again, they had not exported them at the time of data collection. It seems this firm is investing in the national market only.

We found that most firms introduced a maximum of four new services to the market during the period 2006-2009, mostly innovations new to the firm and the national market. Firms that had innovated at world level were in the minority. Table 6.6 summarises the software services innovations commercialised during the period 2006-2009. The empirical evidence presented in Table 6.6 shows that eight firms produced more than four software services innovations.

Table 6.6 New software *services* commercialized by Campinas software firms during the period June 2006- June 2009

Firm number	Total number of innovations	New to firm	New to national market	New to international market	External collaborator
Firm1	7	7	1	1	Yes
Firm2	3	3	0	0	Yes
Firm3	99	99	9	1	No
Firm4	1	1	1	0	Yes
Firm6	3	3	0	0	Yes
Firm7	3	3	3	3	Yes
Firm9	4	4	4	0	Yes
Firm10	1	1	0	0	No
Firm11	1	1	0	0	Yes
Firm12	35	35	0	0	Yes
Firm14	4	2	2	0	Yes
Firm15	30	10	15	5	No
Firm17	3	3	0	0	Yes
Firm18	1	1	1	0	No
Firm19	6	6	6	0	No
Firm20	3	3	2	1	No
Firm21	3	3	2	1	Yes
Total	207	185	46	12	Yes

Source: own elaboration based on fieldwork data collection.

First, Firms 14 and 15 re-employed software services developed in the firm before the period 2006-2009, to provide new services for the national market.

Firms 3 and 15 stand out for the number of commercialised software services at both the firm and the national market. Both firms also innovated at the international level, and in the case of Firm 3 the new service had been exported.[264] The empirical evidence from the in-depth interviews with these two firms showed that they had some common characteristics: i) the firms were between 6 and 10 years old; ii) they had not established external ties to support their innovation, iii) they had graduated from the same incubator; iv) they grew through mergers with other Brazilian software firms; and v) they developed complementary software related to mobility (i.e. they were not competitors).

[264] Section 6.5 below addresses the issue of internalisation of local firms.

Firm 12 showed outstanding innovation performance at the level of the firm, had been a member of the same incubator as Firms 3 and 15 (the incubator was the only external tie created by Firm 12), and had developed software services related to mobility. These findings may indicate that due to the relatively young age of the mobility software industry, which is related also to the development of customised software (e.g. mobile games), there might be more market opportunities for Brazilian software firms to perform and innovate in this industry than in more mature and consolidated software market niches (e.g., development of ERP platforms, historically an oligopolistic market - see Chapter 3).[265]

Firms 1, 20 and 21 had commercialised radical, new to the world innovation. None of them had been incubated.[266] Firm 1 is one of the most successful software firms in the region, has international CMMI certification level 5, exports outsourcing services and has external ties only with customers.

Firm 20 is a case of an informal 'spin-off' from IBM Brasil. The firm's founder is a former IBM Brasil employee who decided to leave IBM to set-up an independent firm to develop software services for IBM. The professional ties between the entrepreneur and IBM guaranteed procurement for the first years of operation and being a supplier to IBM provided immediate reputation.[267]

Firm 21 is one of the oldest and largest local firms in the region and is involved in automated banking, an industry where Brazil has a good international reputation; local firms in automated banking industry have worked to develop sophisticated software products and services (although this industry mostly supplies the domestic market) (Softex, 2005).

Among new software services commercialised during 2006-2009 by Campinas software firms, are the innovations produced by Firm 14. According to Table 6.6 this firm's innovation level is not outstanding in terms of new to the world inventions, Figure 6.1 (p. 176 above) in Section 6.3 shows that this firm created the highest number of external ties to support its innovation activities. Two of its innovations were new to the national market, which means that they were no national

[265] Britto *et al.* (2007: 11) address this issue.
[266] Campinas fieldwork firm interviews.
[267] Campinas fieldwork firm interview.

competitors when their services were commercialised.[268] This firm spun-off from one the most successful software firms in the region, was incubated for two years, and received some private venture capital investment. The venture capitalist was introduced to the firm by one of the incubator's consultants, who thus functioned as a bridge. In turn, the venture capitalist bridged between the firm and a group of international students, who were involved in a month long firm visit. According to an interviewee, this experience with the international students was very productive:

> we got in contact with them [international university department] via the venture capitalist. They [international visitors] spent one month here [at the firm] and we [members of the firm] spent one month at 'x' [international university]. Our firm was used by them [international students] as a case study for a module in one of their programme. Because we [firm] were the case study, they had to get an in-depth understanding of how the firm functioned, and what we do. In explaining these issues to them, we also learnt a lot about our firm. In addition, their [international students] final report was extremely useful in pointing to ways that we could improve the firm's performance in the short term (Campinas Firm 14 interview).

This firm had received grants from FINEP and CNPq. It did not cite the incubator or the venture capitalist as external collaborators in its innovation activities. However, the in-depth interviews reinforced the relevance of these actors to the firm's growth. The firm was in the youngest firm age group (less than 5 years) and had grown from a micro to a small firm during the five year period. The firm is part of the ActMinds export consortium (Chapter 4, Section 4.2) and has an office in the USA to prospect new markets in that country. This discussion suggests: i) that Firm 14 engaged in an effective network as discussed by Burt (1992), evidenced by its direct and tightly-connected ties based on trust, and collaborated for access to reliable and relevant information; and ii) that firms with former links to successful organisations (e.g. Firms 7 and 14) and participate in the network of innovators,[269] are capable of continuous successful performance. However, since Firms 7 and 14 are exceptions in the sample, we cannot reach a firm conclusion about this.

6.4.2 Ongoing innovations

This section investigates ongoing innovation by Campinas software firms in the period 2006-2009, summarised in Table 6.7.

---

[268] Only two other firms (16 and 9) in the same age group as Firm 14 managed to commercialise innovations that were new to the firm and the national market.

[269] As already mentioned, Firm 7 is an informal spin-off from IC-Unicamp.

Table 6.7 Ongoing software innovations by Campinas software firms during the period June 2006- June 2009

Firm number	Number of ongoing innovations	External collaborator
Firm1	0	-
Firm2	1	Yes
Firm3	1	Yes
Firm4	1	Yes
Firm5	2	Yes
Firm6	1	Yes
Firm7	1	No
Firm8	2	Yes
Firm9	1	No
Firm10	1	Yes
Firm11	1	Yes
Firm12	n.a.	Yes
Firm13	1	Yes
Firm14	1	No
Firm15	n.a.	No
Firm16	1	No
Firm17	1	Yes
Firm18	0	-
Firm19	1	No
Firm20	1	No
Firm21	0	-

Legend:
n.a.= not available, firm did not disclose how many ongoing innovations.
Source: own elaboration based on fieldwork data collection.

The empirical evidence shows that most Campinas software firms were developing new software products or services in 2009, and almost half of them had created external ties to support this development. This was as expected because most firms develop customised software, the period of investigation was three years, and there was high likelihood of local software firms providing services or developing products for new customers within that period. Also, because most firms are micro or small firms they are likely to depend on customers to finance new innovations in order to survive in the market. However, close examination shows that only Firm 13 was involved in ongoing innovation with demonstrated demand from a customer; the remaining firms were innovating for prospective demand. This result was unexpected and suggests that ongoing innovation performed locally does not require high fixed investment. However, the investment required for some of the innovations, was high, and was provided by public funding through special programmes offering research grants (Firms 5, 10 and 17).

The evidence presented in Table 6.7 indicates that although the number of innovative firms was high (18 out of 21 firms), the total number of innovations was considerably smaller than the number of commercialised innovations. This applies also to the number of actors engaged in the network of innovators, although the difference was not as much as for the number of innovations.

The investigation of ongoing innovation does not analyse the degree of novelty of innovating firms inventions (i.e. new to the firm, the national or the international market). However, in-depth interviews with firms allowed examination of which firms created new ties to support their innovations, and which had a smaller number of external ties, e.g. Firm 14 and Firm 17. Among firms that created new ties, we found that four Campinas software firms (3, 5, 8 and 10) created external ties to support ongoing innovation, which differed from their strategy for the commercialised innovation stage discussed above, where it seems they innovated without the help of external knowledge (neither business, scientific nor technological). There are three relevant considerations related to these firms.

Firstly, Firms 5 and 10 created external ties with public funding organisations, which indicated that local firms were able to access public funding over time. Secondly, Firm 8 was a 'new' innovator (it did not innovate during the commercialised innovation stage). It had ties with one of the three local incubators, and with another incubated firm; Firm 8 was one of the few firms that was working on two new innovations at the time of data collection.

Thirdly, two of the firms (14 and 17) with the highest number of external ties in the commercialised stage had none or only a very few external ties in ongoing innovation stages. Most of Firm 17's ties were created in the commercialised innovation stage and were with geographically distant actors; ties were mostly loosely-connected and were forged to meet the contractual requirements of customers. This suggests that Firm 17 prioritises the employment of internal knowledge only when developing new products and services.

Firm 14 dispensed with all of its external ties created for the commercialised innovation stage. However, unlike Firm 17, it is a very young firm (less than 5 years old at the time of data collection) and had a good innovation record for commercialised innovation (two innovations introduced at national market level). It was continuing to benefit from the results of these two commercialised innovations at the time of data collection, which together with its accelerated growth and access to public research funding was providing the firm with the capacity to invest in another new innovation project. The project was in its very early stages at the time of data collection, and the firm was performing it on its own. However, according to the interviewee, external ties could be renewed if it appeared they would help the innovation project's development.

6.4.3 Abandoned innovations

Table 6.8 summarises the abandoned innovations for the sample firms in 2006-2009.

The empirical evidences on abandoned innovations by Campinas software firms shows that just over half (12 out of 21) did not abandon innovation activities during the period May/June 2006-June 2009; and most firms that did had no external collaborators (only 3 out of 9 firms that abandoned innovations had external collaborators). The reasons for the innovation being abandoned varied, but close examination shows that they were strongly related to lack of demonstrated demand.

Three firms (11, 15 and 20) abandoned their innovation projects for financial reasons: they had insufficient internal resources to invest in innovation. Chapter 5 (Table 5.4) shows that these three firms were micro or small firms and were younger than 10 years, and their financial capacity to invest in innovations was limited compared to larger and older firms (as claimed by Rothwell and Zegveld, 1982).

Table 6.8 Abandoned software innovations by Campinas software firms during the period June 2006- June 2009

Firm number	Number of abandoned innovations	External collaborator
Firm1	0	-
Firm2	0	-
Firm3	2	No
Firm4	1	No
Firm5	0	-
Firm6	0	-
Firm7	1	No
Firm8	0	-
Firm9	0	-
Firm10	5	Yes
Firm11	1	Yes
Firm12	0	-
Firm13	0	-
Firm14	0	-
Firm15	1	Yes
Firm16	0	-
Firm17	0	-
Firm18	1	No
Firm19	0	-
Firm20	1	No
Firm21	1	No

Source: own elaboration based on fieldwork data collection.

Firm 3 was the only firm that cited lack of demand for the service as the explicit reason for its abandonment of the innovation project. Although Firm 21 is one of the oldest and largest local firms in the region, its reason for abandoning its innovation activity was also evidently related to lack of demand:

> we [firm] developed the project of a new product but realised that the investment for its development was too high and risky for the firm, so we [firm] abandoned the development before it began to cost too much for us [firm] (Campinas fieldwork Firm 21 interview).

The findings on abandonment of innovation suggest that although Campinas software firms do not rely on demonstrated demand as a motivation for innovation (as discussed in Section 6.4.2), they are likely to abandon development activities if they see that the potential demand is unlikely to provide a good enough return from their investment.

6.4.4 Summary

This section investigated and analysed the innovations of Campinas software firms in three innovation stages in the period 2006-2009, that is, commercialised, ongoing and abandoned innovations. Most commercialised innovations were new to the firm; only a small proportion of these innovations (6.5%) were new to the international market. However, most of the innovations new to the international market had not been commercialised abroad (Firm 3's was the exception). These findings indicate that Brazilian software firms are making efforts to catch up with the more sophisticated products and services on the international market. However, they still aim mainly to supply the domestic market. This is a regular characteristic of the Brazilian software firms, as discussed in Chapter 3, Section 3.3.2.

6.5 Internationalisation of Campinas software firms: Some observations

The investigation of the innovations introduced by Campinas software firms and their market insertion allows some conclusions about their absorptive capacity and technological catching-up to the international technological frontier (Rousseva, 2008).

Table 6.9 summarises the findings in Sections 6.2 and 6.3 and suggests that there were outstanding innovative software firms in the Campinas software network of innovators. These firms introduced innovations to the national market (i.e. there were no national competitors at the time of the commercialisation of the innovation) and also to the international market (i.e. the commercialisation of the new software solution or service had no national or international competitors at the time of the innovation).

Table 6.9 Summary of Campinas software firms innovations, 2006-2009

Firm number	Market penetration	Total number of innovations	Commercialised		Ongoing		Abandoned	
			Yes/ No	External collaborator	Yes/ No	External collaborator	Yes/ No	External collaborator
Firm1	Loc, Reg, Natl and Intl	7	Yes	Yes	No	n.a.	No	n.a.
Firm2	Regional	10	Yes	Yes	Yes	Yes	No	n.a.
Firm3	Natl and Intl	102	Yes	No	Yes	Yes	Yes	No
Firm4	Reg and Intl	3	Yes	Yes	Yes	Yes	Yes	No
Firm5	Natl and Intl	4	Yes	No	Yes	Yes	No	n.a.
Firm6	Local	4	Yes	Yes	Yes	Yes	No	n.a.
Firm7	National	15	Yes	Yes	Yes	No	Yes	No
Firm8	Regional	2	No	n.a.	Yes	Yes	No	n.a.
Firm9	National	5	Yes	Yes	Yes	No	No	n.a.
Firm10	Regional	7	Yes	No	Yes	Yes	Yes	Yes
Firm11	National	3	Yes	Yes	Yes	Yes	Yes	Yes
Firm12	Loc, Reg, Natl and Intl	35*	Yes	Yes	Yes	Yes	No	n.a.
Firm13	National	4	Yes	Yes	Yes	Yes	No	n.a.
Firm14	Natl and Intl	8	Yes	Yes	Yes	No	No	n.a.
Firm15	Natl and Intl	31*	Yes	No	Yes	No	Yes	Yes
Firm16	Local	3	Yes	No	Yes	No	No	n.a.
Firm17	Regional	4	Yes	Yes	Yes	Yes	No	n.a.
Firm18	National	2	Yes	No	No	n.a.	Yes	No
Firm19	Regional	7	Yes	No	Yes	No	No	n.a.
Firm20	Natl and Intl	5	Yes	No	Yes	No	Yes	No
Firm21	Loc, Reg, Natl and Intl	4	Yes	Yes	No	n.a.	Yes	No

Legend: Loc= Local; Reg= Regional; Natl= National and Intl= International.

*= firm did not disclose the number of ongoing innovations, total number of innovation refer to commercialised and abandoned innovations.

Source: Own elaboration based on fieldwork data collection.

The relevance of this finding relates to the issue of catching-up by local firms. There seems to have been a shift in the strategy for catching up, with firms attempting some radical (mostly national level, and in some cases international level) innovation.

The number of Campinas software firms that introduced innovations at either national or international level (the latter being more relevant) suggests that these firms are improving their absorptive capacity, crucial for technological catching up. A high level of absorptive capacity is one of the requirements for technological catch-up at firm-level (Rousseva, 2008). The absorptive capacity of software firms is directly related to their technological capability, and customers usually play a crucial role in building absorptive capacity, especially in customised software. This suggests that we should investigate the customers accessed by firms that innovated at the international level.

These firms were involved in radical innovations, that is – Firm 1, Firm 3, Firm 7, Firm 15, Firm 20 and Firm 21 – and most of their customers were large firms (public or private), either Brazilian owned or MNC subsidiaries.[270] These Brazilian software firms were able to improve their absorptive capacity and technological capability, which enabled them to compete with global software suppliers in the international market and to satisfy more sophisticated domestic demand.

This applies to Firm 7. Although Firm 7 had not exported its innovation, it had managed to learn, replicate and improve a technology that previously was supplied to the Brazilian market by a global software supplier. According to the interviewee, the provision of this technology by a local supplier benefited the customer in two ways. It did not have to pay international licence fees for the use of the technology and also was able to obtain more customised software. The local firm did not charge a licence fee and was happy to tailor the technology to the customer's requirements.[271] This is an example of a major and crucial change in the Brazilian software market; until the late 1990s the Brazilian market for sophisticated software was satisfied by global suppliers. However, Brazilian software firms still face a major effort to become global players, including the need to develop complementary technological

[270] The evidence is based on public information available on firms' websites.
[271] Campinas fieldwork Firm 7 interview.

capabilities and the capacity to create reliable and internationally reputed brands (MIT-Softex, 2002; Steinmueller, 2001; Veloso *et al.*, 2003).

6.6 Conclusions

The development of a national software industry depends upon particular historical and institutional events, and the specifics of these events, as well as the industry participants, which suggests a national or regional level of study is appropriate (Heeks *et al.*, 2001; Steinmueller, 2001). An investigation of a national or regional software industry may support understanding of how, for example, the private and public sectors interact in this industry. Due to the complexity of software products, the development of new software requires the employment of different types of scientific and technological knowledge, which demands from firms different combinations of internal competencies, knowledge and experience with external sources of knowledge. These may happen through the creation of ties with supporting organisations such as universities, specialised suppliers, and users. The creation of such ties highlights the sectoral role in the formation of inter-organisational networks of innovators in the software industry.

This chapter investigated the Brazilian software industry in the region of Campinas. Sections 6.2 and 6.3 analysed the governance of the Campinas software network of innovators examining respectively the *structural* and *relational* embeddedness of such network.[272] Before we revisit the findings, a general comment on the incentives for development of the Brazilian software industry both nationally and regionally is appropriate.

The Brazilian national government implemented policies to foster and support development of the local software industry from the late 1970s, and especially since the early 1990s. One of the main national government actions was the implementation of the Softex Programme, to foster interaction among regional actors supposed to be involved in software development (e.g. research universities and R&D organisations). The programme followed the systems of innovation approach that learning-by-interacting is crucial for firms and especially for the development of high-technology industries, which includes the software industry (see Chapter 3).

[272] As explained in Chapter 5, part of the Campinas network of actors was identified outside of this research, i.e. previous to the empirical data collection; this research involves analysing the extent to which these formally identified actors are interacting and how.

Over the 1990s and 2000s several national policies were implemented to support local software industry development, both through changes to the regulatory regime (e.g. amendments to the Informatics Law) and special programmes to provide financial support to local firms (e.g. the Prosoft programme by BNDES and special calls by FINEP). Within this institutional national context, Campinas has become the main Brazilian region for the development of software products and services.

Campinas is embedded in a region that benefits from economic and scientific prosperity. The city is in São Paulo state, the most economically and industrially dynamic Brazilian state (Chapter 4, Section 4.2). One of the country's leading research universities – Unicamp - is based in Campinas. Unicamp runs an incubation programme (Incamp) for technology-based firms and in the early 2000s, set up an Innovation Agency (Inova). The Campinas region also hosts several MNC subsidiaries, R&D organisations and Softex Campinas, the local agent that is still attached to the central administration of Softex National. In terms of regional policies directed to the development of the Campinas software industry, FAPESP (the São Paulo State Research Foundation) is the most important public funding organisation and provides financial support for local firms' research activities through a special programme (PIPE, see Chapter 3). At city level, the Campinas City Council manages two high-technology parks and offers an incubation programme to technology-based firms, both managed by Ciatec (the Company for the Development of Campinas High-Technology Park).

At the national, regional and local institutional and organisation level in relation to infrastructure to foster and support the Campinas local software industry, we examined the governance of the Campinas software network of innovators in terms of its *structural* embeddedness. The main findings reveal that the most frequently accessed and consistent sub-network is the business sub-network (Section 6.2.1). The skills sub-network shows unexpected inconsistency with what would be expected and the technology sub-network is mostly not involved with the network of innovators (Sections 6.2.2 and 6.2.3). In the financial sub-network, the only actor in the network of innovators is FINEP, a public funding agency. Thus, there are no private funding mechanisms supporting innovation activity. However, 4 of the 21 firms interviewed had received venture capital funding, indicating that there was external private investment activity (although at low levels) in local firms during the

2000s. The level of inconsistency in the sub-networks is a sign that even if the relevant ties exist, they may not be functioning positively.

The examination of *relational* embeddedness of the Campinas software network of innovators demonstrates that most direct ties created by local firms are tightly-connected ties, and that in most cases geographical proximity supports the creation of such ties. There are a few exceptions, mostly in the case of Firms 10, 14 and 17. There are a few loosely-connected ties with skills sub-network actors, which in some cases were related to the inconsistency found for this sub-network. Overall, it seems that most firms create external ties for innovation aimed at resolving financial deficiencies and supplying commercial knowledge. Most firms' software developments were based on internal technological and scientific knowledge.

The creation of external ties was almost insignificant in the abandoned innovation stage, suggesting that innovation is abandoned before the stage of creating external ties. The visual representation of the Campinas network of innovators displayed in Figures 6.1, 6.2 and 6.3 suggest that the structure of the network of innovators is mostly fragmented as opposed to well-knit. This finding suggests that there are missing links in the Campinas network of innovators, and that formal interactions among firms, and between firms and other actors are not well diffused.

Our examination of the governance of the Campinas software network of innovators for the three investigated innovation stages, that is, commercialised, ongoing and abandoned innovations, shows that the absolute number of innovations by Campinas firms is high, 265 innovations in the period June 2006-June 2009. However, most are novel only to the firm and are imitative rather than radical innovation. This demonstrates that Brazilian software firms are recombining existing knowledge often applied in local (as opposed to global) and vertical markets. It is common for innovations in software applications to require the understanding and use of localised knowledge. This result was expected, since it is a common feature of local software firms in developing countries. In addition, the low level of diffusion of interactions within the network of innovators was also expected, and relates to the imitative strategies of local firms. Imitative software firms often rely on experience-based learning and numbers of external ties are therefore low. This is the case for the Campinas software firms.

The discussion above provides information to respond to the research questions in Group A, reintroduced below.

Research Question A1

In considering government technology policy to promote firm innovation through networks in the case of the two Brazilian regions selected for analysis, how does regional level network governance and structure influence the effectiveness of policies supporting network creation in Brazil?

The empirical findings show that the network governance and structure of the Campinas software network of innovators has a *mixed* influence on the effectiveness of government technology policies to encourage firm innovation. This is indicated by the different results for the *structural* embeddedness of the network of innovators compared to the results for *relational* embeddedness. The former show inconsistencies in a crucial sub-network, the skills sub-network, and very small involvement of technology sub-network actors. These two findings suggest a negative influence of Campinas software network governance and structure on the effectiveness of technology policies directed to firm-level innovation through the promotion of networks.

The results for *relational* embeddedness indicate that most direct ties are tightly-connected, a crucial feature in interactions aimed at knowledge exchange among actors. This finding suggests a positive influence of the Campinas software network governance and structure on the effectiveness of technology policies for firm-level innovation through the promotion of networks. However, the diffusion of formal ties is low, suggesting that Campinas software firms have not been as responsive, as might have been expected, to government policies aimed at promoting network formation. This may be an indication that there are low levels of interaction between technology policy and network governance and structure in a developing country context.

Research Question A2

What, if any, is the responsiveness of network governance and structure to technology policy aimed at the promotion of networks in Brazil? Does government policy promotion of networks and efforts to control network structure increase the *effectiveness of technology policy aimed at improving the innovative performance of Brazilian software firms?*

This chapter shows that the Campinas network of innovators has a fragmented rather than a well-knit structure, which suggests that there are important missing ties within the network of innovators and that the level of diffusion of formal interactions among this network actors is low.

As already discussed in detail in Chapter 4, Section 4.2, the Campinas ICT industry, including software, has been the target of national, regional and local government technology policies since the early 1990s (the implementation of national policies goes even earlier). These policies include, among other things, support for network formation based on the argument that networks support learning-by-interaction, crucial for the acquisition of new knowledge and its improvement. These policies relate to the training of skilled human resources (higher education), the performance of IT research by the local public research university and R&D organisations, provision of public funding for private research performed by firms, and special programmes to foster the creation of formal ties between the private sectors and knowledge creators.

Based on the findings in this chapter, we see that the responsiveness of the Campinas software firms to government policies aimed to promote network formation is *low* compared to the potential for interactions among firms and between firms and other organisations. The results for the Campinas case show there was *limited* interaction between technology policy and network governance and structure. Taking into account that Campinas software firms show high innovative performance, and that a large share of innovative firms relied on internal sources for developing their innovation activities (especially the development and employment of new knowledge and technology), we can conclude that Campinas software firms prioritised learning-by-experience over learning-by-interacting. This questions the framework of network formation as a government policy instrument to support firms' innovation and regional industrial development.

The Recife software network case study is examined in Chapter 7.

CHAPTER 7 - EMPIRICAL RESULTS II: THE RECIFE SOFTWARE NETWORK

7.1 Introduction

Chapter 7 investigates governance of the Recife regional software network of innovators during the period 2006-2009, and how network governance and structure may have influenced Recife software firms' innovative performances in that period. Chapter 4 (Section 4.3) provided evidence on the structure of the Recife network and showed that, until the mid-1980s, IT related activities in the region were performed mainly by two private organisations. There was little activity after that in Recife until national government policies were implemented the early 1990s to support the region's software development (through the Softex Programme), which, together with state policies implemented by the early 2000s, have supported the emergence and development of the Recife software industry. Recife has become the leading software region in the Brazilian Northeast.

The chapter exploits the indicators developed in Chapter 5 to investigate the features and motivations for firms' creation of formal dyadic ties to support their innovation activities. It draws also upon the indicators of firm-level innovation. Chapter 5 demonstrated that the Recife software network was defined ex-ante to the empirical data collection and here we explore whether there are relations between network members, and how they interact. Section 7.2 addresses issues related to the *structural* embeddedness of the governance of the Recife network of innovators, investigating the evidence provided by the features of dyadic tie creation which are indicative of the consistency of each of the four sub-networks under examination (i.e. the business, skills, technology, and financial sub-networks).

Section 7.3 addresses issues related to the *relational* embeddedness of the governance of the Recife network of innovators and the motivation for and tightness of firms' ties (tightness being determined by the motivation for and frequency of ties). In this section, we introduce a visual representation of the network of innovators and investigate which organisations function or are likely to function as bridges within the network of innovators.

Section 7.4 examines Recife firm level software innovations in three innovation stages– commercialised, ongoing and abandoned. The aim is to identify which firms are innovating, whether they are connected or disconnected to the main cluster of network nodes, and the degree of novelty of their innovations: i) firm level (i.e. new practices or outputs for the firm not new to all other firms); ii) national market level (i.e. practices or outputs new to firms in Brazil); or iii) international market level (i.e. practices or outputs new to the world). Section 7.5 introduces a few observations on the catching-up process of Recife software firms and Section 7.6 concludes with a summary of the evidence to answer the research questions in 'Group A' (introduced in Chapter 5).

7.2 The Recife network of innovators: tie creation and consistency of the four sub-networks

This section investigates the consistency of each of the business, skills, technology and financial sub-networks. We discuss three innovation stages - commercialised, ongoing and abandoned innovations – related to the examination of these sub-networks. The empirical findings on the features of the innovation related ties created by firms demonstrate the consistency of the sub-networks. Consistency is indicated by the level of overlap between the nature of ties created by firms and the organisations' stated, self-defined aims. Section 7.2.1 addresses the business sub-network, Section 7.2.2 the skills sub-network, Sections 7.2.3 the technology and 7.2.4 the financial sub-network. Section 7.2.5 summarises Section 7.2.

7.2.1 Consistency of the business sub-network

The business sub-network was the most frequently accessed by Recife local software firms, that is, there were more firm ties with business sub-network actors than with actors in the other three sub-networks, in all the innovation stages investigated. The results are as follows: i) 9 firms created 16 ties with 7 types of actors for commercialised innovations; ii) 7 firms created 9 ties with 6 types of actors for ongoing innovation; and iii) 3 firms created 4 ties with 2 types of actors for abandoned innovation. As discussed in Chapter 6 (Section 6.2.1), this was partly expected because there are more actors in the business sub-network than in the other three sub-networks; however, the number of ties created was not necessarily expected to be higher than in the other three sub-networks. Table 7.1 re-introduces the features that indicate the consistency of the business sub-network.

Table 7.1 Indicators for consistency of the business sub-network

Business sub-network actors	General aims by sub-network	Features indicating consistency
a) industrial associations b) competitors c) customers d) suppliers e) consultancy firms f) incubators g) private non-profit organisations acting on behalf of the public interests	i) foster and support interactions among firms and between firms and customers ii) support for research funding applications iii) access to information on national and international markets iv) provision of facilities or knowledge for software development, training and workshops v) support the design of business plans and training on organisational matters vi) support software process improvement vii) incubation programmes	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Access to new sources of financing 5. Access to commercial information 6. Innovation co-operation

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

The features of the ties within the business sub-network were fully consistent with it being the sub-network most frequently accessed by Recife software firms. There is a high overlap between the features of each tie created by a local firm (e.g. ‘innovation cooperation’) and the self-defined aims of the business organisations with which ties were formed. Of the business sub-network actors with ties to Recife software firms, customers, other software firms, incubators, and private non-profit organisations are considered further.

The ties created by firms with customers are the most frequent within the business sub-network, and show most of the features in Table 7.1 (with the exception of ‘access to commercial information’). Only Firm 5 gave ‘acquisition of knowledge’ as the reason for tie creation. This was unexpected because the five firms with ties to customers are customised software developers and ‘acquisition of knowledge’ is assumed to be important in that process. However, Firm 5 was perhaps the exception for the following reason.

As discussed in Chapter 3, Section 3.3.1, the development of customised applications requires firms to learn about and fully understand the customer's business and technologies. It requires the addition of new knowledge to pre-existing understanding of how to develop applications. According to the interviewee, once the new knowledge is acquired by the firm, it enhances its expertise and technological capabilities; as a result, the firm increases its internal stock of knowledge, which may be employed in the development of new applications and innovations. Firm 5 was also the only firm to include 'acquisition of technology' as a relevant feature for the tie creation with their customers.[273] It should be noted that 'acquisition of technology' does not seem to imply paid for purchase of a technology (see Chapter 5, Section 5.3.2.3). In the case of Firm 5 'acquisition of technology' occurred in the course of providing services to its customers, which provided the opportunity to access and incorporate new technologies developed by the customer, crucial for the firm's development of customised services. For instance, one of the firm's customers is the most important local IT R&D organisation, acknowledged to be eminent also in Brazil.[274] Both acquisition of knowledge and acquisition of new technologies enhance firm capabilities that may be employed in future innovation projects.

As expected, because all five firms develop customised software the features 'access to new sources of financing' and 'innovation cooperation' were frequently identified as reasons for ties with customers. Although 'access to new sources of financing' was explicitly mentioned by only two of the five firms with ties for financing, our in-depth interviews show that their size (all are micro or small firms) is a constraint to investment in innovations projects without demonstrated demand. These firms stated that customers financed their innovation, which allowed them to survive. As stated by the interviewee:

> here we [the firm] only produce what is demanded, the customer dictates what has to be researched for the delivery of what has been demanded (Recife fieldwork firm interview).[275]

---

[273] Recife fieldwork firm interview.

[274] E.g., the R&D organisation won FINEP Innovation Prize 2010 for the best Brazilian Science and Technology Organisation category. http://www.cesar.org.br/site/c-e-s-a-r-vence-premio-FINEP/, accessed 19 February 2011.

[275] As mentioned in Chapter 5, Section 5.5.2 and Chapter 6, Section 6.2.2, we respect the anonymity of interviewees; for this reason interview numbers are not attached to all quotations. They are replaced by the type of organisation from which the data were collected (firm, organisation, etc.).

This applied also to medium sized and larger and longer established firms:

> we [firm] cannot afford to invest in research or development for its own sake, our budget is very tight and taking the risk is not worth it, because if we develop a product that has no demand we go bankrupt. We tried to invest in development for its own sake about 20 years ago, when we invested in technology and research that were completely new in Brazil. It was so new that the Brazilian market was not ready to use the technology at that time. The good thing about it was that the effort somehow paid off later, because when the Brazilian market demanded the technology we had the expertise to offer it. But we would not do this again, it is far too risky. So our customers not only guide our innovation but also finance it (Recife fieldwork firm interview).

For 'innovation cooperation', most firms stated that development of customised software always involves an innovation new to the firm. This was the case of the two interviewed firms, confirming that software development most frequently involves something new for those engaged in the application development (as discussed by Brooks Jr., 1995).[276]

Three firms had created ties with locally based software firms that develop complementary software. These ties showed the highest frequency of consistent features and included 'acquisition of technology', 'access to commercial information' and 'innovation cooperation'. All of these features were expected. Acquisition of technology and innovation cooperation followed similar patterns to those described above. The development of complementary software provided access and acquisition to technologies (again the acquisition did not involve a purchase) that were new to the interviewed firms before the creation of the external tie. According to the interviewees, the feature 'innovation cooperation' was relevant for both firms in the tie: the aim was cooperation to obtain complementary knowledge to support the development of new software, which benefited both firms and resulted in innovation for both.[277] According to the interviewee,

> the other software firm was interested in collaborating with us [interviewed firm], because we can learn from each other, we are here to innovate and succeed, and some of the local firms believe in that as we [interviewed firm] do. So, the collaboration results in innovation to the both sides, it is a win-win situation (Recife fieldwork firm interview).

[276] Recife fieldwork firms interviews.

[277] Recife fieldwork interviews number 15,16 and 29. It is important to note that the collaborating firms were not part of the sample, therefore we relied only on the primary source of information to make this statement.

The creation of ties between Recife firms and local incubators was related mostly to ‘access to new sources of finances’. There are two incubators in the region that host software firms and provide infrastructure (e.g. office facilities, security, broadband access) and business support at subsidised cost. For prospective customers, an incubator provides the incubated firm with reputation from association with an established organisation. As stated by the interviewee:

> the customers associate your firm with the incubator, thinking that if you have already been accepted by the incubator, your firm must be developing reliable services and is worth of trust (Recife fieldwork firm interview).

Finally, ties between Recife software firms and private non-profit organisations involved NGPD and Softex Recife, which are based in the region and aim to support the development of the local software industry (Chapter 4, Section 4.3). The ties created by local firms with both NGPD and Softex Recife are related to these organisations’ introduction of two local firms to large and sophisticated local customers. In both cases the customers were divisions of the Pernambuco State government, so the referral involved government procurement.

NGPD and Softex Recife have excellent reputations in the region and, according to the interviewees, state government relies on their knowledge for choosing local firms to interact with.[278] From the firms’ perspective the referrals were crucial because they gave access to large customers that previously had used providers in other Brazilian regions (often in the Southeast). As stated by the interviewee:

> the state government feels that they can trust NGPD and Softex knowledge to refer them to a reliable local firm, they [state government] know that if a firm is referred by these organisations the likelihood of the firm disappointing them is minimal, because we know that if anything goes wrong our image with the customer and within the local community [Porto Digital] gets damaged, so we make sure that the project is successful. What is very important about these referrals is that now we [local firms] have finally got access to the most important local customers such as the State government (Recife fieldwork firm interview).

Another outcome of ties created through NGPD, which facilitated referral of local firms to potential customers and referrals among firms for collaboration was the creation of a consortium of local competing firms in Recife, mediated by NGPD.[279] As explained by the interviewee,

---

[278] Recife fieldwork organisational interviews.
[279] Recife fieldwork interviews numbers 13, 20, 21 and 32.

> the [Pernambuco] State Secretary of Education contacted NGPD with an idea for a project to be applied in the state schools. NGPD approached us to investigate if we could deliver the project and we said that we could not develop it alone, we did not have all the necessary expertise and personnel to deliver the project. But we said that if other local firms got involved we could do it. So, we all got in contact, we [local competitors] know each other, we are neighbours here [in Porto Digital]. But NGPD mediated the meetings, they are a neutral organisation, it was easier to negotiate with our competitors if a neutral organisation was involved. We sat together, and agreed that we could found a new firm based on a consortium type of arrangement. It has been a great success. We are now at the trial stage and with ideas to offer the product and services to other state governments and maybe private schools as well. The project opened very good business opportunities for us [firms involved in the project] (Recife fieldwork firm interview).

The empirical evidence discussed above demonstrates the relevance of local organisations, such as SoftexRecife and NGPD, for supporting the growth of Recife software firms. The level of consistency suggests that the ties created with the business sub-network were positive, although this is not typical of systems of innovations in developing countries (Cassiolato *et al.*, 2003; Chaminade and Vang, 2008; Lastres, 2007; Lundvall *et al.*, 2009a).

7.2.2 Consistency of the skills sub-network

The skills sub-network was the second most frequently accessed sub-network by Recife local software firms in the innovation stages considered: i) five firms created six ties with four types of actors for the commercialised innovations stage; ii) six firms created nine ties with four types of actors for ongoing innovation; iii) there were no ties created with the skills sub-network actors for the abandoned innovation stage.[280] The skills sub-network was partly consistent, with universities and research foundations being the most frequently accessed types of actors. Table 7.2 re-introduces the features that indicate consistency for the skills sub-network.

[280] Identification of part of the network actors was done previous to questionnaires and interviews (Chapter 5).

Table 7.2 Indicators for consistency of the skills sub-network

Skill sub-network actors	General aims by sub-network	Features indicating consistency
a) universities b) technical colleges c) continued education organisations d) research council e) research foundation	i) IT training in different levels, such as: undergraduate, Masters, Doctorate and Post-Doctorate and continued education ii) support new knowledge creation through basic or applied research funding programmes iii support new knowledge creation through funding programmes for development activities	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Innovation co-operation

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

Two findings stand out in the examination of ties created with the skills sub-network. Firstly, the highest frequency of ties created by firms were with the national research council (CNPq) and the local research foundation (FACEPE), ties that were associated with the inconsistency found in the sub-network. All the firms that created ties with CNPq (4 and 14) and FACEPE (2, 4, 7, and 16) were for ‘access to new sources of financing’. This was expected as both CNPq and FACEPE provide funding to support firm research related activities. However, no mention of ‘acquisition of knowledge’ and ‘acquisition of technology’ was unexpected because the stated aims of both CNPq and FACEPE include provision of funding for the promotion of the scientific and technological development of firms through the performance of in firm research activity.[281] Hence, local firms did not associate ties with CNPq and FACEPE for funding research with improvements to their own scientific or technological development, which demonstrates inconsistency in the skills sub-network.

Secondly, the empirical findings show that the four firms that had created ties with local research university departments (Cin-UFPE and Design) mentioned all the

[281] http://www.FACEPE.br/modules.php?name=Content&pa=showpage&pid=1, and http://www.cnpq.br/english/cnpq/index.htm, accessed 19 February 2011.

features that denote consistency in the skills sub-network, that is, ‘access to open information source’, ‘acquisition of knowledge’, ‘acquisition of technology’, and ‘innovation cooperation’.[282] This result was expected, although ‘innovation cooperation’ requires further comment. Local firms stated that the local research university departments involved in ties develop high quality (although rather academically related) scientific knowledge, and also are open to collaborations with the private sector through the development and employment of applied research (this issue was discussed in Chapter 4, Section 4.3). Also some UFPE faculty members are happy to collaborate with local firms, so the knowledge produced by the university would be translated into practical applications.[283] As stated by the interviewee:

> we [the firm] spotted an opportunity to develop a project with UFPE design department because they have expertise in one area where the firm lacked capability. We contacted one of the faculty members using a personal relationship and they [design department] were happy to collaborate, they feel that they are contributing to the economic development of the region when their knowledge is put into practical and real things (Recife fieldwork firm interview).

The ties with Cin-UFPE and the empirical evidence show the efforts made by Cin-UFPE to engage with the private sector, a goal that has been pursued by the department since the early 1990s, as discussed in Chapter 4 (Section 4.3).[284]

The discussion and interview extracts above could be interpreted as local research universities devoting their scientific efforts towards applied knowledge (or to knowledge with a purpose) related to the needs of the local private sector. This would confound those that criticise the roles played by research universities in developing countries, which often are seen as being too concerned with the international knowledge frontier at the expense of the needs of their local embedded regions. The role of universities is beyond the scope of this thesis; however, if public policy making were aimed exclusively at the private sector, a shift in the role of local research universities towards the production of practical knowledge might ultimately impede the catching-up process for laggard regions.

---

[282] As mentioned above, acquisition does not refer to the purchase of new technologies.
[283] Recife fieldwork interviews numbers 10, 12 and 29.
[284] Recife fieldwork organisational interview.

This could be relevant for an investigation of innovative firms engaged in innovator networks, and might provide insights for public policy formulation and effectiveness in a network framework.

7.2.3 Consistency of the technology sub-network

The technology sub-network was the third most frequently accessed sub-network as follows: i) five firms created five ties with two different technology sub-network actors (two different R&D organisations) for commercialised innovations; ii) four firms created four ties with two different technology sub-network actors (the same two R&D organisations as in the commercialised innovation stage); and iii) one firm created one tie with one technology sub-network actor – an R&D organisation for the abandoned innovation stage. Table 7.3 re-introduces the features that indicate consistency for the technology sub-network.

Table 7.3 Indicators for consistency of the technology sub-network

Technology sub-network actors	General aims by sub-network	Features indicating consistency
a) research organisations b) development organisations	i) perform basic or applied research, for, among others, the commercialisation by the private sector ii) development activities for, among others, the commercialisation by the private sector.	1. Acquisition of knowledge 2. Acquisition of technology 3. Innovation co-operation

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

The technology sub-network shows a high level of consistency when the ties created by local software firms with local R&D organisations involve ‘acquisition of knowledge’, ‘acquisition of technology’ and ‘innovation cooperation’. However, we also found some features related to inconsistency of the technology sub-network. Investigation of the consistency and inconsistency of this sub-network requires a discussion of ties created with each of the three R&D organisations.

CESAR was the local R&D organisation most frequently accessed by Recife software firms. As mentioned in Chapter 4, Section 4.3, CESAR has become the anchor of the Recife software network of innovators, both because it employs the highest number of personnel devoted to IT development activities locally (about 400 employees in 2009)[285] and because of its excellent reputation in the national IT market. Four firms created ties with CESAR, two of them are affiliated to CESAR and two are not.

The ties created by firms not affiliated to CESAR are consistent, that is, they were forged for reasons of 'acquisition of knowledge', 'acquisition of technology' and 'innovation cooperation'. This result was expected, and 'innovation cooperation' reflects CESAR's investment in and reputation for being a R&D organisation devoted to the development of IT innovation.

Investigation of ties created with CESAR show that the two firms were affiliated to the organisation at the time of the data collection.[286] In one case, all innovation activities developed by the firm (number not disclosed for reasons of confidentiality) were performed in partnership with CESAR.[287] The other firm was incubated in CESAR's incubation programme and was part of CESAR.par.[288] Also, CESAR is a minor shareholder in the firm. This firm's ties were created for 'acquisition of knowledge' and 'acquisition of technology', demonstrating consistency in ties created with the technology sub-network actors.

The firm with no ties with CESAR's software developers requires further consideration. In this one case, the firm had been incubated at CESAR, and was part of CESAR.par and CESAR was a minority shareholder in the firm. As an incubated firm, it benefited from the subsidised infrastructure offered by the incubator, legal assistance over labour regulations and taxes (provided by CESAR's administrative department), and advice on business plans (Recife fieldwork firm interview). However, the tie was created only with the incubator programme and not with CESAR's software developers, which related to inconsistency of the technology sub-network, as follows:

> we [firm] do not employ external knowledge in the development of our [firm] services. We were incubated at CESAR, but our relationship with them did not go beyond the incubation facilities and subsidies (Recife fieldwork firm interview).

---

[285] Recife fieldwork organisational interview. See Ritz (2008) for extensive discussion on private non-profit Brazilian IT research centres.

[286] One firm is CESAR's spin-off firm, however still part of CESAR.par, which means that CESAR is the firm's main shareholder. The other firm was incubated at CESAR, and is also part of CESAR.par, however in this case CESAR is a minority shareholder.

[287] Recife fieldwork firm interview.

[288] As informed in Section 4.3 (Chapter 4 above), CESAR.par is the division of CESAR responsible for financial investments in other business partners.

The fact that this firm has not created ties with CESAR developing division partly indicates inconsistency in the technology sub-network. It could be expected that being part of the organisation would lead to ties between the firm and CESAR other than exploitation of the latter's incubation facilities and services. One might expect ties for the 'acquisition of knowledge' or 'acquisition of technology', based on CESAR's mission to 'transfer information technology knowledge between the industry and the academia in a self-sustainable way'.[289] Although the incubation programme does not explicitly advertise that technological knowledge developed in CESAR's main activities is accessible to incubated firms, the advertisement for the incubation programme declared CESAR's strong involvement with the incubated businesses, and provision of services that would support start-ups and add value, build firm competencies and access networks that would generate positive results for start-ups.[290] These services, competencies and networking could be understood as being technologically related. The empirical evidence from our close examination suggests that the lack of ties created with CESAR explicitly for 'acquisition of knowledge' and 'acquisition of technology' confirms the partial inconsistency of the technology sub-network.

Another firm had no ties for 'acquisition of knowledge' and 'acquisition of technology' with a local R&D organisation despite having been part of its incubation programme. This again suggests possible inconsistency in the technology sub-network, and also dysfunctional ties between local firms and supporting organisations, which the interview tends, *a priori*, to confirm:

> what we get from the organisation [local R&D organisation] is infrastructure at low cost, that is all. They [incubator] say that they offer consultancy, but in reality it does not happen, we [interviewed firm] are on our own, but we are doing well. The low infrastructure cost has been a good benefit for us (Recife fieldwork interview number 11).

However, the self-defined, stated mission of the R&D organisation, and closer examination of its expertise, shows that the consultancy offered by the organisation is business related rather than technological (i.e., the partial inconsistency would be in the business sub-network instead of in the technology sub-network). In addition, this particular R&D organisation does not hold specific competence in ICT, providing no foundations for expectations of direct tie creation with the main unit.

[289] www.cesar.org.br, accessed 08 November 2008.
[290] Idem.

This confirms again the need for close examination to fully explain the functioning and structure of network of innovators (see also Chapter 5, Section 5.4.1).

In addition to ties created with the two R&D organisations discussed above, another local firm had a formal tie with a third local R&D organisation, for the abandoned innovation stage. As expected, tie creation involved the 'acquisition of knowledge' and the 'acquisition of technology' and therefore indicated consistency of the technology sub-network.

7.2.4 Consistency of the financial sub-network

The fewest ties were those created by firms with the financial sub-network. Table 7.4 re-introduces the features that indicate consistency for the financial sub-network.[291]

Table 7.4 Indicators for consistency of the financial sub-network

Financial sub-network actor	General aims by sub-network	Features indicating consistency
a) private and public banking organisations b) public funding organisations c) venture capitalists d) government authorities	i) grants or loans for firm-level basic or applied research and development activities ii) venture capital for start-ups iii) tax incentives for firm-level innovation activities iv) creation of technological parks or incubation programmes	1. Acquisition of knowledge 2. Acquisition of technology 3. Access to new sources of financing

Source: own elaboration, adapted from Table 5.1 (Chapter 5).

Recife firms were involved in ties only with one national public funding agency - FINEP, which indicates that this sub-network is infrequently connected to local firms. None of the 17 firms interviewed had ties with FINEP for the commercialised innovation stage and one of the four firms that had created ties with FINEP for the ongoing innovation stage was still awaiting a response to a grant application.

In addition, the two firms with ties to FINEP for the abandoned innovation stage did not receive funding from the agency, which explains the abandonment of their

[291] As explained above, some of the Recife network's actors were identified previous to empirical data collection.

innovation development. The empirical evidence on the features of ties created with FINEP indicates that the financial sub-network is partly consistent, explained by the following. All seven firms that involved FINEP in their innovation projects (through existing or prospective ties) indicated ‘access to new sources of financing’ as the reason, which is consistent with the expected nature of this sub-network. However, it is FINEP’s mission to support innovation in firms (among others) and only one firm in the sample identified FINEP with ‘innovation cooperation’. Hence, we conclude that there is inconsistency in the tie creation.

7.2.5 Summary

Our investigation of the consistency of the four sub-networks provides the following evidence. Firstly, most Recife software firms perform their innovation activities in collaboration with organisations with which they have formal ties. Secondly, the business sub-network displays the highest level of consistency among all investigated sub-networks, that is, there was a high overlap between the features of ties identified and those indicated in Table 7.1. In addition, the ties created with supporting private, non-profit, local organisations are relevant for firms accessing new customers. Thirdly, there is low engagement of actors in the skills and technology sub-networks, where lack of ties for ‘acquisition of knowledge’ and ‘acquisition of technology’ demonstrates partial inconsistency of these sub-networks. Fourthly, there is no engagement of the private funding sector with Recife private firms innovation activities, which rely on funding from public organisations for their innovation activities, thus, the ties created by firms are not fully consistent with other missions of FINEP.

Investigation of the consistency of the four sub-networks is complemented by an investigation of the motivations for ties among firms, and between firms and other network actors, which is the object of Section 7.3.

7. 3 Network Relations for Innovating and Non-Innovating Firms: Recife

This section investigates the *relational* embeddedness of the Recife software network of innovators related to three issues. Firstly, how many and which firms perform innovation activities, either alone or in collaboration with other network actors to support their innovation. Secondly, we examine the tightness of the ties among Recife software firms and between firms and other organisations (tightness being based on motivation for and the frequency of ties). Thirdly, we examine which firms and network actors function (and are more likely to function) as bridges within the network of innovators. We examine these three issues for each innovation stage analysed in the thesis, that is, commercialised innovations (Section 7.3.1), ongoing innovation (Section 7.3.2) and abandoned innovation (Section 7.3.3). The representation of the network of innovators for each innovation stage supports the empirical evidence.

7.3.1 Network of innovators for commercialised innovations in the period 2006-2009

This section investigates the Recife software network of innovators for the commercialised innovation stage during the period under analysis (May 2006 to May 2009) providing evidence for the three issues mentioned above.

Innovative firms and inter-organisational ties

How many and which firms innovated during the period 2006-2009 and whether they created external ties, shows that almost all Recife firms innovated during that period.[292] This is as expected because, as discussed in Chapters 3 and 6, most developed software involves some degree of innovation. We found that 70% of the sample of interviewed firms had external ties to support their innovation activities. In addition, five firms were engaged in the main cluster of nodes (which accounted for 17 actors), 4 firms were engaged in the secondary cluster of nodes (which accounted for 8 actors), and there were isolated clusters which accounted for two triad ties (by Firms 5 Firm 8) and one binary tie (by Firm 12). This allows us to conclude that the Recife network of innovators is fragmented as opposed to having a well-knit structure. This characteristic suggests diffusion of information within the network and effectiveness to access new and valuable information by network actors, will be low (Burt, 1992).

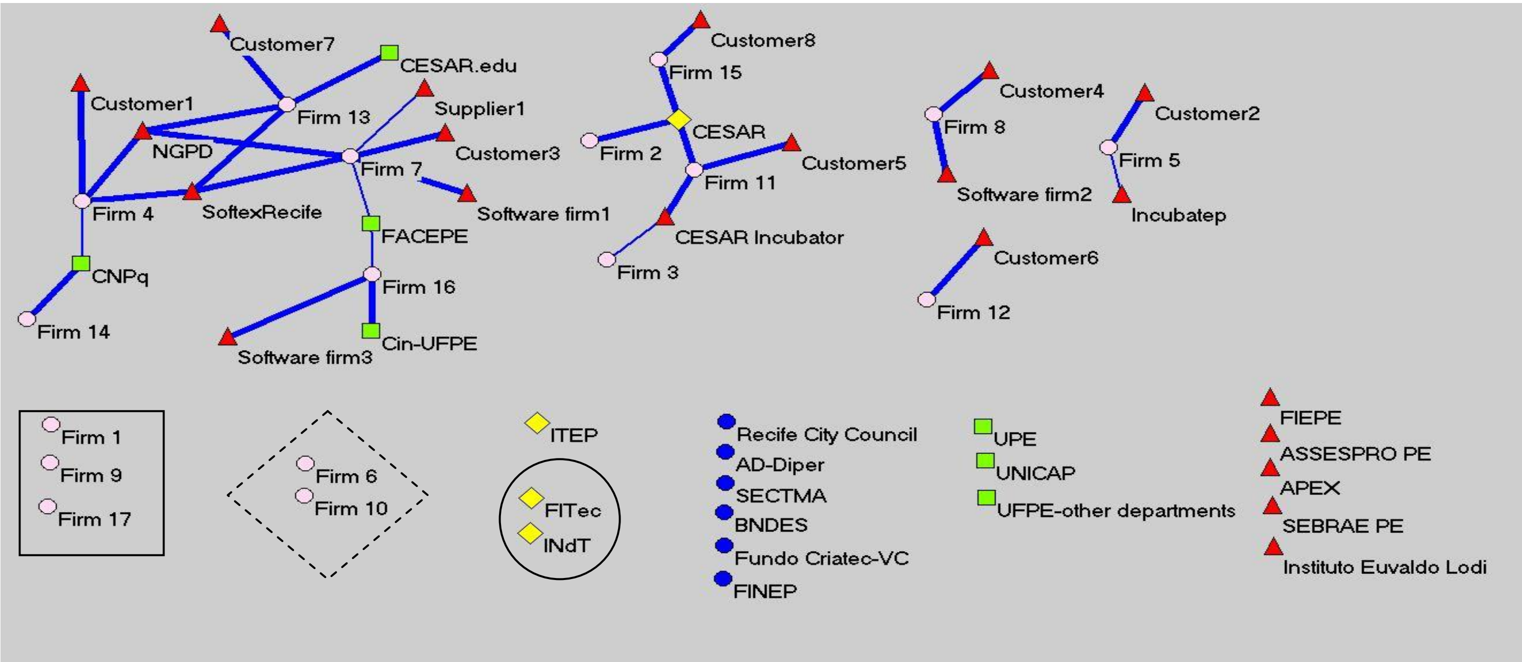
Tightness of inter-organisational ties

[292] Firms 6 and 10 are exceptions. Both had innovated previous to 2006 and since then had developed new versions of the innovation, i.e. had been involved in incremental innovation. In addition, in the two cases the customers who financed their innovations are large customers and account for a significant part of the firms' revenues. These customers helped to keep Firms 6 and 10 in business during the period analysed in this thesis. Recife fieldwork firms interviews.

Although the structure is not well-knit, the majority of the ties are tightly-connected as opposed to loosely-connected ties, which relates to the second issue discussed in this section. This finding indicates that the creation of ties is motivated mainly by issues such as trust, collective identity, personal relationships, and knowledge availability and accessibility. In most cases geographical proximity supports the creation of tight ties, which corroborates claims that local contexts support trust building and cognitive proximity (as discussed by Asheim and Gertler, 2004).[293] These findings are as expected because direct ties are frequently associated with tight connections (as discussed by Giuliani networks breed trustworthy relationships). Figure 7.1 is a visualisation of the Recife software network of innovators for the commercialised innovation stage during the period April 2006-April 2009. It differentiates tightly-connected and loosely-connected ties, which actors are engaged in which clusters of nodes, and supports understanding of which actors are acting as bridges within the network of innovators. Direct loosely-connected ties, motivated by opportunities and financial issues, were an unexpected finding.

[293] Although geographic proximity does not always explain tightly-connected ties, for instance, because of labour mobility, as mentioned by Boschma (2005).

Figure 7.1 The Recife software network of innovators: commercialized innovations during 2006-2009



Legend:
● Firms
♦ Technology sub-network
■ Skills sub-network
▲ Business sub-network
● Financial sub-network
Tight connections =
Loose connections =
□= Firms that did not create external ties to support their commercialised innovation during 2006-2009.
○= Autonomous private non-profit R&D organisations originally set up by multinationals that were disengaged from the network of innovators.
◊ = Firms that did not commercialise new software products of services during the period 2006-2009.
Source: own elaboration based on fieldwork data collection.

There are six cases of loosely-connected ties in the Recife software network of innovators, related to Firms 3, 5 and 7 for the business network, and Firms 4, 7 and 16 for the skills sub-network. Among the loosely-connected ties with business sub-network actors, two were with local incubators. Firm 5 had a tie with Incubatep, motivated by ‘costs’ and ‘opportunity’. Firm 5 chose the incubation programme offered by ITEP (rather than the others available) based on geographic proximity to Cin-UFPE, where the entrepreneurs were studying:

> the fact that Incubatep is just across the road [from Cin-UFPE] was a major issue for us, because we are still doing our masters at Cin-UFPE, so we can go between venues in a few minutes. And also, the trainees that work here [in the firm] on fixed-term contracts are often still studying there [Cin-UFPE], so it is easy for them to work for us between lectures or lab sessions. It is easier for everyone (Recife fieldwork firm interview).

Firm 3 had a loose tie to CESAR and referred to the motivation of ‘cost’. It had chosen to be incubated at CESAR because of the low infrastructure costs and the legal and financial administrative assistance provided (incubation at CESAR provides automatic membership of CESAR.par, and the benefits of CESAR’s centralised administration), and support in preparing business plans.[294]

Only one firm had a tie with local suppliers, and this was a loosely-connected tie and was based on the motivation ‘opportunity’. The interviewee also mentioned geographical proximity as an important motivation for creating this tie. This indicates that closeness may be associated with loosely-connected ties, although this tends to be the exception.

The loosely-connected ties with the skills sub-network actors, FACEPE (Pernambuco State Research Foundation) and CNPq (national research council), were motivated by ‘cost’ and ‘opportunity’. These loosely-connected ties between local firms and FACEPE and CNPq confirm the inconsistency of the skills sub-network discussed in Section 7.2. However, one firm (Firm 14) had a tightly-connected tie with CNPq, which was based also on ‘trust’ and ‘knowledge availability and accessibility’.

From the firms’ perspective grants offered by FACEPE were biased towards ‘academic’ type research proposals. According to one firm, the requirements in FACEPE’s research grant calls for proposals are difficult and demanding to fulfil:

[294] Recife fieldwork firm interview.

> we [the firm] are applying for a good grant by a new call from FACEPE, when we could hire a researcher to work for the firm in the next two coming years. But look, FACEPE requires the applicant to be not employed at the time of the application, to hold at least a Master's degree and have at least five years of experience. Where are we going to find someone exactly like that? A well qualified and experienced researcher is unlikely to be unemployed; if they are good they are employed. Usually we [the firm] have to find people and persuade them to come to work for us (Recife fieldwork firm interview).

The statement above demonstrates the paradox in the funding organisation's requirements. This perhaps is related to concerns that funding might be used to poach talent from rival firms, creating unintended consequences. However, it makes it difficult for applicants to meet the requirements for receiving funding. It suggests the presence of a similar phenomenon as in Campinas with regard to the strong bias of public funding organisations towards academic type applications and research and poor timing of calls for public funding in relation to commercial needs. It shows that there are important actors in the region (this laggard problem having been overcome) but an absence of potentially important ties due to institutional rigidity inherent in Brazilian public organisations (see Pacheco and Corder (2009), and Chapters 3 and 6 in this thesis).

The empirical evidence on the dyadic ties created by Recife software firms shows that most direct ties are tightly-connected ties, which may be of relevance for the role of organisations functioning as bridges in the network of innovators, the third issue investigated in this section.

Bridging organisations within the network of innovators

The relevance of bridging organisations is based on the argument that one of the advantages from participation in a network is the possibility of learning-by-interacting. Therefore, bridging organisations prospectively support the creation of ties among firms, and between firms and other network actors. Burt (1992) addresses this issue in his discussion of the efficiency and effectiveness of networks (see also Chapter 2, Section 2.4.1). The representation of the network of innovators in Figure 7.1 (p. 222 above) suggests that there are some organisations that indirectly bridge between firms in the main cluster of nodes, and secondary cluster. We examine the functioning of these organisations further.

Figure 7.1 shows that four organisations could function as bridges in the Recife network of innovators; two are part of the skills sub-network –CNPq and FACEPE, and two are part of the business sub-network -NGPD and SoftexRecife. However, CNPq and FACEPE are unlikely to do so because it is not part of their remit. Their funding programmes are arranged through open calls, and blind assessment of firms' applications. However, some of FACEPE's funding programmes require the participation of academic researchers in firms' project applications, which would mean that FACEPE would be functioning indirectly as a bridge. Which researchers and which organisations are invited to participate in the firm's application project is down to the firm and not FACEPE. The same could apply to CNPq, however the research council more often supports research in firms by funding secondment of university students through bursaries and scholarships rather than research grants.

With regard to the main cluster of nodes, NGPD and SoftexRecife may function as bridges because of their position within the network of innovators, which can be seen in Figure 7.1 and the close examination showing that firms are tied to customers, other local software firms and local organisations through NGPD and SoftexRecife (e.g., the case of Firm 13). This emphasizes the relevance of close examination to support a full understanding of how networks of innovators function and are structured. However, Figure 7.1 shows that the firms connected to NGPD overlap with the firms that are connected to SoftexRecife, which raises the issue of whether only a limited number of firms has been able to access or receive support from these two organisations. The empirical findings from the interviews with firms show that the number of firms benefiting from these organisations' support is not limited to those represented in Figure 7.1. For instance, Firm 1 has used SoftexRecife facilities (testing laboratory), and Firm 10 had support from NGPD for writing a grant application to FINEP.[295]

Most Recife software firms are associated to SoftexRecife, therefore the organisation is knowledgeable about the firms based in the region and their expertise. Although SoftexRecife has closer relationships with some firms than others through the creation of formal ties, the interviews do not indicate that SoftexRecife would be

[295] Recife fieldwork Firm 1 and Firm 10 interviews.

likely to favour certain of the associated firms.[296] Finally, 9 of the 17 firms interviewed believe that NGPD represents one of the strongest assets of the Recife network.[297] This suggests that NGPD has come to represent the Recife community of firms: 'NGPD has good access to firms. They are the link between the sub-groups of firms based in the Recife' (Recife fieldwork firm interview).

Investigation of the secondary cluster of nodes in Figure 7.1 (p. 222 above) shows that CESAR is the main bridging organisation, and ties local firms indirectly. Three firms, 2, 11 and 15, have direct ties to CESAR. Although Firm 3 did not include CESAR as an actor directly related to their innovations, this firm is part of CESAR.par and we can conclude, therefore, that CESAR can bridge between Firm 3 and other network actors in the cluster of nodes.

All the ties between firms and CESAR are tightly-connected ties, suggesting that firms are likely to regard referrals from CESAR as reliable, possibly increasing the chances of CESAR's bridging activities being successful. This finding was expected since CESAR has become the anchor of Recife software network during the 2000s. However, Figure 7.1 shows CESAR's disengagement from the main cluster of nodes within the network, and also shows that CESAR has its own cluster of nodes. This was an unexpected finding: it was expected that CESAR would be tied to the main cluster of nodes mainly because it is the main IT R&D organisations in the region (and among the most important in the country) and CESAR was identified by nine firms as being an important asset in the region.[298] For instance:

> CESAR promotes new ideas and the engagement of new actors in the region. For example, CESAR was chosen by FINEP to manage the PRIME [FINEP Programme] programme in Pernambuco. Even the actions of NGPD end up linked with CESAR (Recife fieldwork firm interview).

and,

> The main strength of the region is CESAR's reputation. Silvio Meira [CESAR's chief scientist] is a very important communicator in and for the region. CESAR has implemented several important initiatives, such as the partnership with Motorola to bring its testing centre to Recife. They also attracted Microsoft for the region (Recife fieldwork firm interview).

---

[296] The close relationship of SoftexRecife with a group of firms was identified through SoftexRecife's referral of local innovative firms, which were included in the sample of interviewed firms of this thesis.
[297] Recife fieldwork interviews numbers 6, 14, 15, 16, 18, 20, 21, 23, and 29.
[298] Recife fieldwork interviews numbers 4, 6, 11, 14, 15, 16, 17, 18, and 19.

However, the representation of the network of innovators in Figure 7.1 does not do full justice to the role played by CESAR within the Recife network of innovators. For instance, based on this representation it might be assumed that the disengagement of CESAR from the network would not cause much disruption to the evolution of the network. The close examination of empirical evidence, however, provides a much better understanding of the role played of the organisation in the local network of innovators. It shows that in the course of its existence, CESAR has become the network's anchor and its reputation has had spill-over effects for the organisations in the network. Its withdrawal from the network (should, perhaps, its headquarters be relocated) would cause huge disruption to the evolution of the network. CESAR has also built an important community in the region, based mainly in its relationships with Cin-UFPE faculty members and their former and current undergraduate and post-graduate students.[299] This community also includes other organisations established in the region during the 2000s. This community is based on relationships among actors with common professional backgrounds, who may engage in communities of scientific and technological development through the creation of ties based on common understandings of particular problems (see Salter and Martin, 2001 and Pavitt, 1987; see also Chapter 2, Section 2.2.2). The evidence from the interviews shows that CESAR has the potential to bridge between local actors based on its trustworthy reputation in the region. These findings are corroborated by the engagement of CESAR in the main cluster of nodes in the ongoing innovation stage, which is analysed in Section 7.3.2.

7.3.2 Network of innovators for ongoing innovations in the period 2006-2009

This section investigates the Recife software network of innovators for the ongoing innovation stage, during the period 2006-2009 and addresses the following issues: i) how many and which firms perform innovation activities, either alone or in collaboration with other network actors; ii) the tightness of the ties created among Recife software firms, and between firms and other organisations; and iii) which firms and network actors function (and are more likely to function) as bridges within the network of innovators.

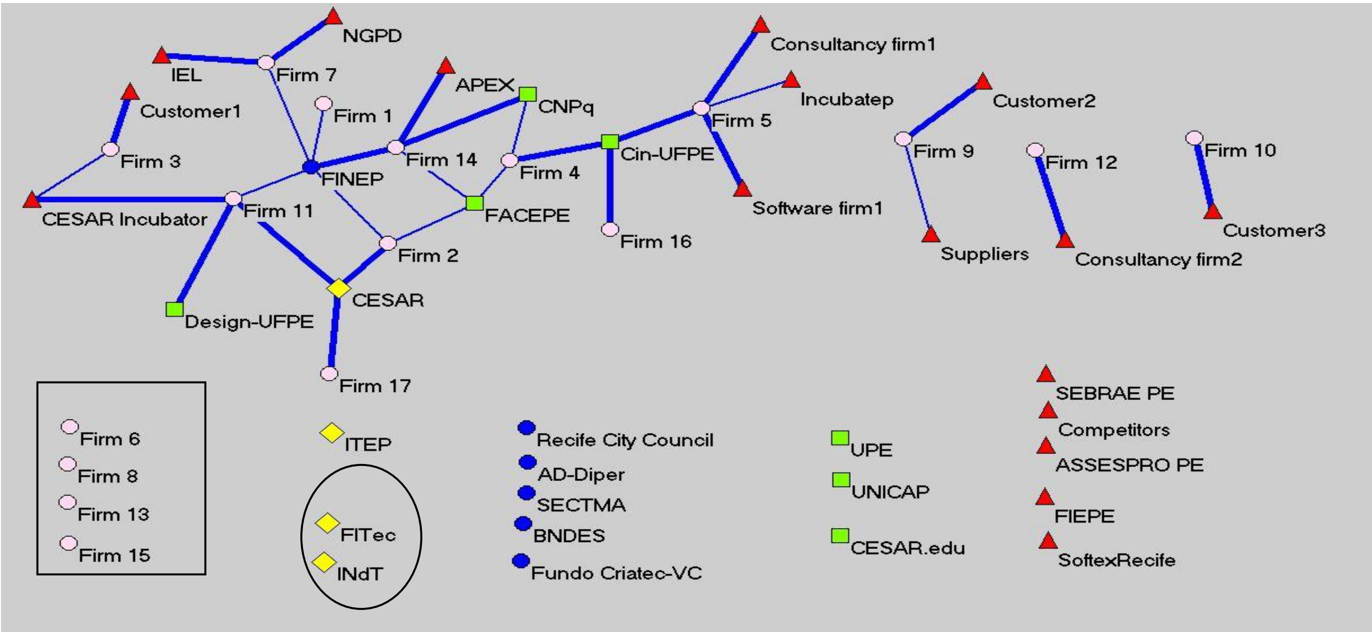
Innovative firms and inter-organisational ties

[299] As discussed in Chapter 4, Section 4.3, CESAR is a spin-off from Cin-UFPE.

The empirical evidence on ongoing innovation performed by Recife software firms shows that there were some changes to the network of innovators represented in Figure 7.2 below. The first change is that the number of non-innovative firms during the ongoing innovation stage increased compared to the commercialised innovation stage analysed in Section 7.3.1, from 2 firms to 4. Only Firm 6 was non-innovative during the ongoing innovation stage as well as in the commercialised innovation stage. Firm 13 (consortium of firms) was set up in 2008 to deliver a customised software product/service, which was commercialised in early 2009 on a trial basis, because of which there is no ongoing innovation recorded at the time of data collection.[300] Firms 8 and 15 had commercialised new products and services close to the time of data collection and were still benefiting from these innovations, which required constant updates which these firms did not consider to be innovations.

[300] Recife fieldwork firm interview.

Figure 7.2 The Recife software network of innovators: ongoing innovations during 2006-2009



Legend:
● Firms
♦ Technology sub-network
■ Skills sub-network
▲ Business sub-network
● Financial sub-network
Tight connections =
Loose connections =
□= Non-innovating firms, April 2009.
○= Autonomous private non-profit R&D organisations originally set up by multinationals disengaged from the network of innovators.
Source: own elaboration based on fieldwork data collection.

The second and significant change in the ongoing innovation stage is that all Recife software firms involved in ongoing innovations had created external ties to support their innovation activity. As expected, most of the direct ties created by Recife firms are tightly-connected ties. In addition, although the representation of the network of innovators in Figure 7.2 shows that the network of innovators is fragmented (as opposed to well-knit), in this innovation stage there was only one main cluster of nodes (rather than 2 as in the commercialised innovation stage), involving 10 innovative firms and the other 14 network actors. Three firms had created isolated ties, Firm 9 created a triad, and Firms 10 and 12 had created binary ties.

Examination of the structure of the network of innovators shows that some of the ties in the commercialised innovation stage had broken down, especially those with business and skills sub-network actors. These were not always loosely-connected ties, as might have been expected. The completion of innovation projects financed by FACEPE explains the break down of ties with that organisation; Firms 7 and 16 were no longer being financed by FACEPE in the ongoing innovation stage. In the case of SoftexRecife and NGPD the discontinued ties had been tightly-connected ties. In the case of Firm 13 there was no involvement in ongoing innovations at the time of data collection.

More important than the discontinued ties, were the new ties created by firms in the ongoing innovation stage. Firstly, Recife software firms accessed funding from FINEP, which engaged in the main network of innovators through the creation of ties by five firms.[301] The majority of the ties created with FINEP were loosely-connected, that is, they were more frequently related to the motivations of ‘opportunity’ (there was a call where the firm fitted the requirements) and ‘costs’ (FINEP provides non-reimbursable grants). This confirms the partial inconsistency of the financial sub-network discussed above. Secondly, the ties with business organisations that were new compared to the commercialised innovation stage, such as the Euvaldo Lodi Institute (IEL) and the Brazilian Trade and Investment Promotion Agency (APEX), were tightly-conencted ties. In the case of the tightly-connected tie between Firm 14 and Apex, this was based on ‘trust’ and ‘knowledge availability and accessibility’:

[301] Firm 1 was the only firm in the sample that was awaiting a response to its research funding application.

> we [the firm] feel confident that they [APEX] will release the funding on the scheduled date. You know, not all government funding organisations follow that rule; delays in release of funding are common. And also we trust that they have the adequate knowledge to support us with the exports (Recife fieldwork firm interview).

Thirdly, firms disengaged from the main cluster of nodes in the commercialised stage were engaged in the ongoing innovation stage. For instance, Firm 5, which was isolated in its own cluster of nodes in the commercialised stage; and Firm 11, which was engaged only with CESAR’s cluster of nodes. In the ongoing innovation stage CESAR’s cluster of nodes was tied to the main cluster, which represents an improvement in the network (although this finding should be balanced against close examination - see above). However, this engagement was supported by a tie created with FINEP, which demands some clarifications regarding the role of FINEP as a bridging organisation. The investigation of which firms and network actors function (or are likely to function) as bridges within the network of innovators is the third issue investigated in this section.

Bridging organisations within the network of innovators

The representation of the Recife software network of innovators in Figure 7.2 indicates that the following organisations could play bridging roles: FACEPE, CNPq, FINEP and Cin-UFPE. As discussed above, bridging organisations can be crucial to the development of networks, because they foster the creation of direct ties among firms, and between firms and other organisations.

The potential bridging role of FACEPE, CNPq and FINEP is undermined by their aims and the looseness of firms’ ties with them. These organisations do not have ‘bridging’ as one of the objectives. FINEP, FACEPE and CNPq offers funding through open calls and special programmes, which are blind reviewed by internal evaluators. Several firms identified FINEP as an important source of finance (FINEP offers non-refundable research funding) which suggests that post-application efforts by FINEP to bridge between firms would be rather ineffective.

Figure 7.2 shows that Cin-UFPE acts as a bridge in the network in the ongoing innovation stage, and is potentially very likely to foster the creation of direct ties among local firms. This is because most local software entrepreneurs are graduates of Cin-UFPE, from undergraduate or postgraduate courses and often have good trusting relationships with former tutors. The ties created by Firms 5 and 16 with

Cin-UFPE were motivated by personal relationships with their Masters' Degree supervisors. Also, Cin-UFPE has an excellent reputation among the local community and in Brazil, which, in addition to tightly-connected ties with firms, increases the chances of firms following up prospective referrals from Cin-UFPE.[302] A Cin-UFPE faculty member mentioned his mediation of a partnership between two local firms:

> there is this local entrepreneur that I have a close relationship with. Some time ago he came to me and said that he was looking for a foreigner partner to co-develop a new service with his [local entrepreneur] firm. I asked why he was looking abroad if a local firm could do the same job. He said that he worried about his business plans being 'stolen' by a neighbouring firm that is owned by someone he knows, they have lunch together, they have coffee together every week. So I intervened: I proposed a non-disclosure contract that would guarantee no 'stealing' by either party. And it worked! They became partners, are co-developing the innovation and together are more likely to succeed (Recife fieldwork organisational interview).

Finally, Cin-UFPE has been making efforts since the early 1990s to be more pro-active in its relationships with the private market. The establishing of the pre-incubation programme, Recife BEAT, and the creation of CESAR, were two significant organisational changes resulting from this effort. Therefore, it can probably be assumed that Cin-UFPE faculty members would be willing to put firms in touch with one another and to make recommendations were they to see an opportunity for local firms to work together in a way that would benefit them and the region.

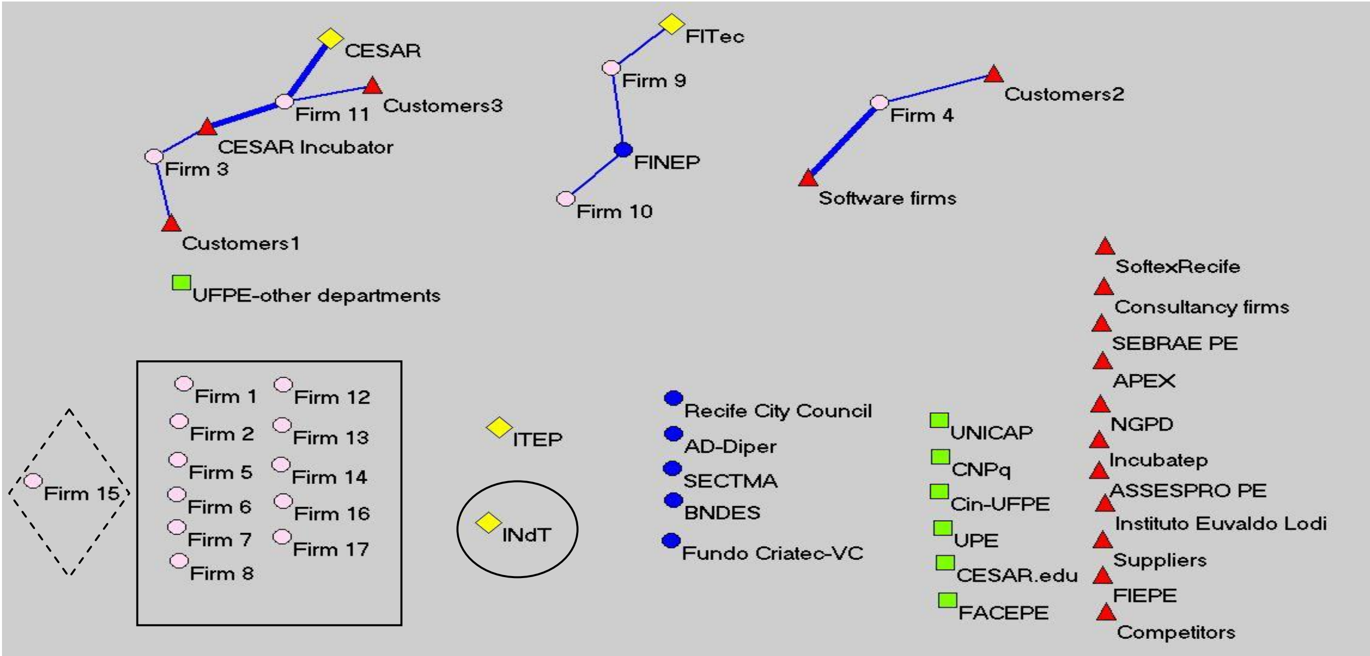
7.3.3 Network of innovators for abandoned innovations in the period 2006-2009

The empirical findings for the Recife software network of innovators for the abandoned innovation activity stage show that the majority of software firms were not forced to abandon these activities during the period 2006-2009, and that most that did had created an external tie. This empirical evidence corroborated previous findings regarding the innovation stages examined in Section 7.3.1 and Section 7.3.2, when most firms created external ties to support their innovations.

With regard to the tightness of the ties created by firms, most direct ties were loosely-connected. This was an unexpected result; in the two innovation stages analysed above (commercialised and ongoing) most direct ties were tightly-connected.

[302] Firms and other organisations stated that Cin-UFPE is one of the strongest assets of the Recife software network. Recife fieldwork interviews numbers: 1, 4, 6, 7, 8, 12, 21, 25, and 32.

Figure 7.3 The Recife software network of innovators: abandoned innovations during 2006-2009



Legend:
● Firms
♦ Technology sub-network
■ Skills sub-network
▲ Business sub-network
● Financial sub-network
Tight connections =
Loose connections =
□= Firms that did not abandon innovation projects during the period 2006-2009.
○= Autonomous private non-profit R&D organisations originally set up by multinationals disengaged from the network of innovators.
◊ = Firms that did not create ties for the abandoned innovations during the period 2006-2009.
Source: own elaboration based on fieldwork data collection.

The higher proportion of loosely-connected ties in Figure 7.3 combined with the empirical evidence, indicates that loosely-connected ties are more vulnerable to breaking down under pressure, even when they involve technology sub-network actors. For instance, Firm 9 was depending on approval of a FINEP grant to develop its innovation; when it was not approved, the tie was broken. In the absence of public incentives or subsidies, ties among actors are not likely to be maintained. Figure 7.3 highlights also that only FINEP was in a position to act as a bridging organisation in the abandoned innovation stage. However, FINEP was unlikely to foster the creation of direct ties between Firms 9 and 10 for the reasons discussed in Section 7.3.2.

7.3.4 Summary

This section investigated three characteristics of the Recife software network of innovators: i) whether local software firms created external ties to support their innovation activities in the innovation stages of commercialised, ongoing and abandoned in the period 2006-2009; ii) the tightness of dyadic ties created by firms to support their innovation activities; and iii) the organisations that functioned as bridges in the network of innovators.

The analysis of the three innovation stages reveals a pattern: i) most local firms create external ties to support innovation, and the majority are with business sub-network actors; ii) the network of innovators is more likely to have fragmented clusters of nodes as opposed to a well-knit structure, although the ongoing innovation stage showed less fragmentation; iii) most direct ties are tightly-connected ties, except in the abandoned innovation stage; iv) although bridging features in the commercialised and ongoing innovation stages are related to the business sub-network generally, empirical evidence shows that Cin-UFPE (skills sub-network) and CESAR (technology sub-network) are the most prominent actors that could play bridging roles.

Analysis of the dyadic ties created by firms in this section, and the examination of the consistency of the sub-networks in Section 7.2 provides evidence on the governance of the Recife network of innovators. The *structural* and *relational* embeddedness of this network is indicative of the institutional context in which local firms innovated in the period April 2006-April 2009. Section 7.4 investigates the innovation performed by Recife local firms, and discusses how network governance influenced innovation in the region.

7.4 The Recife software network: innovation at the firm-level

This section investigates Recife software firms' innovations in the commercialised, ongoing and abandoned innovation stages. We show which firms are innovating, whether they are connected or disconnected to the main cluster of nodes, and how many innovations and what degree of novelty do they produce. Section 7.4.1 investigates innovations commercialised in the period 2006-2009; Section 7.4.2 investigates the innovations that were being developed at the time of data collection (ongoing innovations). Section 7.4.3 investigates the innovations abandoned during the same period. Section 7.4.4 summarises section 7.4.

7.4.1 Commercialized innovations: 2006-2009

The empirical findings revealed that most commercialised innovations are software services: 113 new services and 11 new products. The former involved 10 firms and the latter 7 firms).

Table 7.5 New software *products* commercialised by Recife software firms during the period April 2006-2009

Firm #	Total number of innovations	Innovation new to the firm	Innovation new to national market	Innovation new to international market
Firm 1	0	n.a.	n.a.	n.a.
Firm 5	0	n.a.	n.a.	n.a.
Firm 7	2	2	1	0
Firm 9	1	1	1	0
Firm 13	1	1	1	0
Firm 14	3	3	3	2
Firm 15	1	1	1	0
Firm 16	2	2	2	0
Firm 17	1	1	1	0
Total	11	11	10	2

Legend: n.a.= not applicable
Source: own elaboration from fieldwork, April 2009.

Table 7.5 shows that most firms commercialised one new product in the period 2006-2009. The most notable finding showed in Table 7.5 is that all Recife firms that commercialised new software products introduced an innovation to the national market, that is, these firms produced software that had not been present in any other Brazilian software firm at the time of the commercialisation. This suggests that firms had improved their absorptive capacity and indicates that the formerly lagging Recife region is showing positive results in relation to IT technological catch up (Section 7.5 discusses this further). Firms 14 and 16 produced more than one innovation, and Firm 14 introduced two new-to-the-world innovations.

The innovations achieved by Firm 16 required external ties with actors in the business and skills sub-networks. For one of its innovations Firm 16 created a tie with a local firm that develops complementary software. For the other innovation, it forged ties with Cin-UFPE (the only example of a firm tie with this organisation) and FACEPE, the public funding agency that part financed the innovation. An interviewee told us that the involvement of Cin-UFPE was crucial because it supported the firm's access to new knowledge which positioned it at the national technological frontier. The tie with Cin-UFPE was supported by the enrolment of one of the firm's creators on a Professional Masters Degree course offered by Cin-UFPE. This course is more market orientated than Cin-UFPE's regular Masters Degree in Computing Science. The tie with the university group was motivated by a relationship with a Cin-UFPE professor who supervised the interviewee's Masters Dissertation. This suggests that personal relationships played an important role in the creation of ties with the local research university and underlines that actors in the same communities have shared knowledge and understandings about specific problems, which increases the likelihood of ties between them. This corroborates the findings in Section 7.3.

Firm 14 stands out because it is the only firm that introduced an innovation at the international level, and had been exporting. This firm is one of the most successful software firms in the Recife region and competes in the international market:

> the international market always comes first for us [interviewed firm], we actually develop our products in the English language, and then later assess which products would be interesting to the national market, when chosen products are translated into Portuguese (Recife fieldwork firm interview).

There are two interesting findings related to Firm 14. First, the firm was incubated as part of the Cin-UFPE incubation programme 'Recife BEAT', and its first product was the result of a Master's level research by one of the firm's founder. Although the firm did not name Cin-UFPE as a formal collaborator during the period under analysis (the firm is in the age group 6-10 years - Chapter 5, Table 5.5), the interviewee stressed the firm's good relationships with the organisation:

> there are always students from Cin-UFPE here in the firm, they [Cin-UFPE students] come as trainees to develop part of their dissertations, we are happy to give our codes to them because we know that they use for scientific purposes (Recife fieldwork firm interview).

Second, Firm 14 creates ties with CNPq for international level innovations, and is the only firm in the sample with tightly-connected ties to this organisation. According to the interviewee, CNPq's funding allows them to hire highly-qualified staff, which provides the firm with technological frontier knowledge.

The investigation of new commercialised software services shows that most Recife firms innovated in services rather than products. However, this preponderance is due mostly to the very high number of service innovations commercialised by three firms, which account for 90% of total firm level innovation. Table 7.6 summarises the innovation performance of local firms that commercialised new software services during the period 2006 to 2009.

Table 7.6 shows that there were much smaller numbers of national level innovations (compared to new software products) and especially international (new to the world) innovations, and shows that four firms stand out for innovative performance.

Firm 5 had the highest number of innovations, 44, but these were all firm level innovations (i.e. innovations already present in other firms in the market). Firm 5 created external ties with customers and a local incubator to support their innovation. According to the interviewee, the number of innovations is because the firm works on the basis of one-off projects, as follows:

> we [firm] only work for projects with proven demand, we are a start-up and cannot afford to have a different business model. And every project demands a novelty that has to be learnt by us, so the way I see it is that every project is an innovation, it may not involve only new things to us, of course we [firm] re-employ previous knowledge, but there is always something new to be learnt, and in that sense it is an innovation (…) but we are aware that the new knowledge employed by us has already been used by others (Recife fieldwork firm interview).

Table 7.6 New software *services* commercialised by Recife software firms during the period April 2006-2009

Firm #	Total number of innovations	Innovation new to the firm	Innovation new to national market	Innovation new to international market
Firm 1	3	3	2	1
Firm 2	1	1	0	0
Firm 3	1	1	1	0
Firm 4	2	1	1	0
Firm 5	44	44	0	0
Firm 6	0	n.a.	n.a.	n.a.
Firm 7	2	2	1	0
Firm 8	1	1	0	0
Firm 9	0	n.a.	n.a.	n.a.
Firm 10	0	n.a.	n.a.	n.a.
Firm 11*	18	18	18	15
Firm 12*	40	40	Not answered	Not answered
Firm 13	0	n.a.	n.a.	n.a.
Firm 14	1	1	0	0
Firm 15	0	n.a.	n.a.	n.a.
Firm 16	0	n.a.	n.a.	n.a.
Firm 17	0	n.a.	n.a.	n.a.
Total	113	113	23	16

Legend:
n.a.= not applicable
* = Firm produces both services and products and was unable to state whether the innovation referred to a service or product.
Source: own elaboration from fieldwork, April 2009.

Firm 1 had produced fewer innovations compared to Firms 5, 11 and 12, for instance. However, most of Firm 1 innovations were new to the national market, and one was new to the world although at the time of data collection had not entered the export market. The firm is directing its investments mostly to the domestic market. Firm 1 is among the group of a few firms with no external ties to support their innovation:

> we [firm] use only internal knowledge to develop our products and services, but in technical terms there is one firm that does all the R&D for us, we [firm's entrepreneurs] created a spin-off firm to develop our R&D. We created this new [spin-off] firm because it reduced our tax liability; in reality, the firms are part of the same firm. Sometimes we outsource part of our activities, because there are local firms that can do things quicker and more cheaply than we can ourselves. But all the required knowledge is developed here (Recife fieldwork firm interview).

Firm 11 had involvement in all the types of innovations in Table 7.6, with most new to the international market. According to the interviewee most of these innovations involved new technologies, and some involved the application of a new business model not previously used for the type of software developed. Firm 11 was incubated at CESAR and, as discussed above, benefited from the incubator infrastructure and from CESAR's reputation (with regard to prospective customers) and expertise in software development.[303] The firm was connected to CESAR's independent cluster of nodes (Figure 7.1, p. 222 above) and therefore disengaged from the main cluster within the network of innovators; the firm has external ties with customers in addition to CESAR. As mentioned above, CESAR is one of the most important IT R&D organisations in Brazil, and the innovative results of Firm 11 suggest that firms with access to successful organisations may be able not only to benefit from their successful experience, but also to reproduce success in their own contexts. However, we cannot generalise this because the history and performance of Firm 11 is an exception in the sample.

7.4.2 Ongoing innovations

Table 7.7 summarises the ongoing innovation stage for Recife software firms during 2006-2009. The empirical evidence for this stage shows that most (13) Recife software firms were involved in developing new software products or services at the time of the data collection.

All the firms involved in ongoing innovation stage had created external ties to support their innovation activities. This was as expected because most firms had developed customised software during the period of investigation, and one would expect local firms to have responded to new customer demands. Also, most firms in the sample are micro or small firms, and it is reasonable to assume they depend on customers to finance financing their innovation. However, close examination shows that not all Recife innovative firms invested in new innovation projects in response

[303] According to the interviewee, the firm has had *ad hoc* collaborations with independent developers that are part of a virtual community. These collaborations occur whenever the firm reaches its technical or creativity capacity in the development stage. The firm uses email to contact independent developers who may be located anywhere in Brazil. The developers produce part of the firm's products, but there is no legal contract regulating the relationship: 'these collaborations are very informal, and there is a lot of trust involved. We email the developer, who confirms whether he/she can deliver the product, and once we make a deal we trust that they [developers] will deliver what we [firm] need. We pay them direct'. Recife fieldwork firm interview.

to market demands; this includes Firms 1, 2, 7, 14, 16 and 17. Four firms (1, 2, 7 and 14) had created external ties and relied on public funding to invest in software products or services to respond to potential demand.[304] Other firms involved in ongoing innovation stated that their new products or services had been financed by their customers (e.g. Firms 3, 5, 9, 10, 11 and 12).[305]

Table 7.7 Ongoing software innovations by Recife software firms during the period June 2006- June 2009

Firm number	Number of ongoing innovations	External collaborator
Firm1	1	Yes
Firm2	4	Yes
Firm3	1	Yes
Firm4	n.a.	Yes
Firm5	3	Yes
Firm6	0	-
Firm7	1	Yes
Firm8	0	-
Firm9	1	Yes
Firm10	1	Yes
Firm11	1	Yes
Firm12	1	Yes
Firm13	0	-
Firm14	n.a.	Yes
Firm15	0	-
Firm16	1	Yes
Firm17	1	Yes
Total*	16	n.a.

Legend:
n.a.= Firm did not disclose how many ongoing innovations.
*= Total is incomplete because Firm 4 and Firm 14 did not disclose how many ongoing innovations.
Source: own elaboration based on fieldwork data collection.

There were fewer innovations in the ongoing than in the commercialised stage (16 and 113 respectively), but the number of external ties created by innovative firms had increased. Most ties were with actors in the business sub-network, followed by the skills, finance and technology sub-networks. Some firms, such as Firms 4 and 7, had relinquished ties created in the commercialised innovation stage; however, both these firms had created other ties, indicating that ties may be abandoned and

[304] Firm 1 was still awaiting the results of a grant application to FINEP, at the time of the data collection.
[305] Firm 4 did not disclose this information.

reformed or replaced as to respond to the requirements of different innovation projects. Firms 4 and 7 had abandoned their ties with SoftexRecife, ties that in the commercialised innovation stage had provided referrals to new customers. Neither firm was using SoftexRecife for their ongoing innovation.

Another finding with regard to the creation of external ties for innovation is the increasing number with funding organisations from both the skills and financial sub-networks. Three firms had set up ties with FACEPE and five firms had ties with FINEP. This suggests that Recife software firms are increasingly more able to access public funding offered by local organisations (e.g. FACEPE) or national funders (e.g. FINEP).

Table 7.7 shows also the prominence of Firm 2 for total number of ongoing innovations - four compared to one for the majority of firms. Firm 2's number of ongoing innovations was higher than its number of commercialised innovations (1) and it had retained all existing ties as well as creating new ones for the ongoing innovation stage. These were with two public funding organisations. Its ongoing innovation was not related to demonstrated demand. Firm 5 also stands out. It created a new tie with Cin-UFPE to support its ongoing innovation, and to connect it to the main cluster of nodes (the firm formerly was in an isolated node). It also is involved mostly in one-off projects, which probably explains its higher number of innovations compared to other firms.

7.4.3 Abandoned innovation

This section investigates innovations abandoned by Recife software firms in the period 2006-2009 (Table 7.8).

The empirical evidence reveals that most firms did not abandon any of their innovation activities during the period 2006 until 2009. Activities that were abandoned were mostly for reasons related to lack of financial resources within the firm (Firms 3 and 15), or from customers (Firm 3), or failure to access external funding from public funding organisations (Firms 9 and 10). Firm 4, though, had a different reason: loss of trust in a partner collaborating over software development. The partner was located in another region of Brazil, and it is possible that geographical distance had a negative effect on this tie. These findings suggest that although Recife software firms do not rely completely on demonstrated demand when initiating innovation activity (as discussed in Section 7.4.2), they are likely to cease development if they are left with only internal means of financing the activity.

Table 7.8 Abandoned software innovations by Recife software firms during the period June 2006- June 2009

Firm number	Number of abandoned innovations	External collaborator
Firm1	0	n.a.
Firm2	0	n.a.
Firm3	1	Yes
Firm4	1	Yes
Firm5	0	n.a.
Firm6	0	n.a.
Firm7	0	n.a.
Firm8	0	n.a.
Firm9	2	Yes
Firm10	1	Yes
Firm11	1	Yes
Firm12	0	n.a.
Firm13	0	n.a.
Firm14	0	n.a.
Firm15	1	No
Firm16	0	n.a.
Firm17	0	n.a.
Total	7	n.a

Legend:
n.a.= Firm did not disclose how many ongoing innovations.
Source: own elaboration based on fieldwork data collection.

7.4.4 Summary

This section investigated and analysed innovation in Recife software firms in three innovation stages, during the period 2006-2009. All the commercialised product innovations were new to the firm and most (90%) were new to the national market. A very small number (18%) of product software innovations was new to the international market. For commercialised software services innovations, all were new to the firm, 20% were new to the national market and 14% were new to the international market. These results show that Recife software firms' innovation in products is more fundamental than their innovation in software services. The considerably higher number of software service innovations compared to software products shows that Recife software firms are more competitive in software services. Also Recife software firms success at commercialising a substantial number of innovations suggests that local firms are making an effort to catch up with other regions in the country, and penetrate regional and national markets historically supplied by leading national competitors or international suppliers.

The investigation of the three innovation stages and the representations of networks show that only in the abandoned innovation stage was there participation from an inter-regional network actor. The tie with this actor was loosely-connected, and eventually was abandoned. This finding suggests that the Recife network of innovators should beware of network sclerosis (Grabher, 1993, and Grasenick *et al*, 2008) especially when there is a predominance of tightly-connected ties in the network. At the same time, some ties were with customers located in regions other than Recife, which may reduce the risks of sclerosis. Section 7.5 addresses the importance of customers for Recife software firms, focusing on their contribution to catch-up.

7.5 Internationalisation of Recife software firms: some observations

Investigation of the innovations introduced by Recife software firms and their market penetration leads to some conclusions related to their absorptive capacity and technological catch-up to the national and international technological frontiers. Both are important issues because the region is considered a laggard in software production compared to other Brazilian regions.

Table 7.9 summarises the findings in Sections 7.2, 7.3 and 7.4 and suggests that some Recife software firms stand out as very active software innovators. The findings in Table 7.9 reveal that some firms access customers based outside the Recife region, which is relevant for catching-up. The firms that innovated in the national market seem to have developed beyond innovation based on imitation and (at least to a degree) caught up with national firms in other Brazilian regions. The close examination of national and international level innovation shows that although only Firm 14 was exporting its innovation at the time of the data collection, other local firms had successfully penetrated the national market and were competitive in Brazil, and some had been involved in export (vide Table 7.9).

Table 7.9 Summary of Recife software firms innovations, 2006-2009

Firm number	Market penetration	Total number of innovations	Commercialised		Ongoing		Abandoned	
			Yes/ No	External collaborator	Yes/ No	External collaborator	Yes/ No	External collaborator
Firm1	National	4	Yes	No	Yes	Yes	No	-
Firm2	National	5	Yes	Yes	Yes	Yes	No	-
Firm3	Regional	3	Yes	Yes	Yes	Yes	Yes	Yes
Firm4	National	3*	Yes	Yes	Yes	Yes	Yes	Yes
Firm5	Regional	47	Yes	Yes	Yes	Yes	No	-
Firm6	Reg; Natl and Intl	0	No	-	No	-	No	-
Firm7	Regional	5	Yes	Yes	Yes	Yes	No	-
Firm8	Regional	1	Yes	Yes	No	-	No	-
Firm9	Local, Reg; Natl and Intl	4	Yes	No	Yes	Yes	Yes	Yes
Firm10	Natl and Intl	2	No	-	Yes	Yes	Yes	Yes
Firm11	Natl and Intl	20	Yes	Yes	Yes	Yes	Yes	Yes
Firm12	Natl and Intl	41	Yes	No	Yes	Yes	No	-
Firm13	Local	1	Yes	Yes	No	-	No	-
Firm14	Natl and Intl	4*	Yes	Yes	Yes	Yes	No	-
Firm15	Natl and Intl	2	Yes	Yes	No	-	Yes	No
Firm16	National	3	Yes	Yes	Yes	Yes	No	-
Firm17	Natl and Intl	2	Yes	No	Yes	Yes	No	-

Legend: Loc= Local; Reg= Regional; Natl= National and Intl= International.

*= firm did not disclose the number of ongoing innovations, total number of innovation refer to commercialised and abandoned innovations.

Source: Own elaboration based on fieldwork data collection.

Since penetration of more sophisticated markets indicates better developed absorptive capacity, and absorptive capacity is crucial for technological catching-up (Rousseva, 2008), we can conclude that in the first decade of 2000 there was an important shift in the Recife software industry. Up to the late 1990s, the region was lagging some way behind other Brazilian software producing regions, but is showing (relative success) in catching up.

Although Recife software firms, for the most part, are following an imitative strategy, the fact that some are innovating at national and international level and accessing sophisticated customers (in their own or other Brazilian regions, or abroad), suggest a major change in the Recife software market. Until the 2000s most of the region's sophisticated software demand was satisfied by software suppliers in other national or international regions. Nevertheless, the catch-up that has been achieved is limited to a small number of firms. Recife must find ways to enable firms to improve the degree of novelty of their innovations which will allow them to access new markets.

7.6 Conclusions

The development of a national software industry depends on historical and institutional events and their specifics, as well as the industry participants. This requires study at the national or regional level of the industry (Heeks *et al.*, 2001; Steinmueller, 2001). An investigation of the software industry in a country or region may provide greater understanding about how, for example, the private and public sectors interact. The complexity of software products and their innovative activities require scientific and technological knowledge at different levels. Software firms may need to combine internal competencies, knowledge and experience with external sources of knowledge, which is enabled by the creation of external ties with supporting organisations such as universities, specialised suppliers, and users. Creation of such ties highlights the role of inter-organisational networks of innovators in the software industry.

This chapter investigated the Brazilian software industry in the region of Recife, reputed to be a laggard in this industry at national and international market levels. Sections 7.2 and 7.3 analysed governance of the Recife software network of innovators by examining the *structural* and *relational* embeddedness of the network.

It is important to highlight that most of network actors were identified before empirical data collection, and the examination of *structural* and *relational* embeddedness allows us to identify which network actors were interacting and how (Chapter 5). Examination of the *structural* embeddedness of the Recife software network of innovators showed that there is a high level of consistency in most of the sub-networks analysed, and in the case of the business sub-network complete consistency. The participation of two supporting business organisations, SoftexRecife and NGPD, was crucial for supporting local firms access to sophisticated customers, which demanded an up grading in the firms' technological capabilities.

Examination of the *relational* embeddedness of the Recife software network of innovators demonstrated that most direct ties created by local firms were tightly-connected ties and that, in most cases, geographical proximity supported the creation of such ties. We found also that most firms created external ties to support their innovation activity. This applied especially in the ongoing innovation stage when all the firms studied had ties to one or more external organisations and also most firms were connected to the main cluster of nodes, suggesting an improvement in the structure of the network of innovators compared to the commercialised innovation stage. The Recife network software of innovators showed a change from a fragmented structure to a well-knit one. This suggests that there were fewer 'missing links' in the network of innovators and that formal interactions among firms and between firms and other actors were better diffused. With regard to the abandoned innovation stage, we found that most firms that abandoned innovations during the period 2006-2009 had external ties for innovation.

We found that the absolute number of innovations by Recife firms was quite large for a laggard region, with a relatively new industry. The total number of innovations in the period April 2006 to April 2009 was 147. Most of these innovations were new to the firm, which demonstrates that Recife software firms are following an imitation rather than a more fundamental innovation strategy. An alternative interpretation would be that because many of these innovative firms are small firms, their innovation strategies are largely dictated by customers, whose requirements are not related to more radical innovations. Recife software firms are recombining existing knowledge, often directed to local (as opposed to global) and vertical markets. This was an expected result, since it is a common feature of local software firms in laggard regions to adopt such a strategy as a first step towards penetrating local and national markets.

However, we found also that most Recife software firms had external ties to support their innovation, and there was a medium level of diffusion of interactions within the network of innovators (especially in the ongoing innovation stage). This was unexpected, because the knowledge base of imitative software firms often relies on experience-based learning and the number of external ties in this case is expected to be lower. The discussion above contributes to answering the research questions which are reintroduced below.

Research Question A1

In considering government technology policy to promote firm innovation through networks in the case of the two Brazilian regions selected for analysis, how does regional level network governance and structure influence the effectiveness of policies supporting network creation in Brazil?

The empirical findings discussed above identified that the governance and structure of the Recife software network of innovators had a varied influence on the effectiveness of government technology policies to promote firm innovation. This was demonstrated by the conflicting results for *structural* and *relational* embeddedness of the network of innovators. The former indicates some level of inconsistency in the skills sub-network (although this was related primarily to funding), in addition to the low engagement in the network of innovators by crucial actors such as university departments. For the technology sub-network we found that only one R&D organisation was tied to local firms, and was related more to its own cluster of nodes. These two findings suggest the network governance and structure of the Recife software may have partly jeopardized the effectiveness of technology policies directed at firm-level innovations through the promotion of networks.

The results on the *relational* embeddedness indicated that most direct ties were tightly-connected ties, a crucial feature in interactions aimed at knowledge exchange among actors. In addition, the efforts of key network actors to support the development and growth of Recife local firms, seem to have been successful although to a limited degree. These findings suggest that the network governance and structure of the Recife software network have *positively influenced* the effectiveness of technology policies directed at firm-level innovations through the promotion of networks. In addition, the diffusion of formal interactions shows improvements when different innovation stages were compared, which is partly due to the response to local policies implemented in the region aimed at fostering collaborations.

Research Question A2

What, if any, is the responsiveness of network governance and structure to technology policy aimed at the promotion of networks in Brazil? Does government policy promotion of networks and efforts to control network structure increase the effectiveness of technology policy aimed at improving the innovative performance of Brazilian software firms?

The empirical findings discussed in this chapter show there was a moderate level of diffusion of formal interactions in the Recife network of software innovators. Although the network of innovators was generally fragmented, there were signs of a trend towards a well-knit structure. Also, interactions among key local actors in the network of innovators were having some effect on the development and growth of Recife local software. Hence, the results for the Recife case show that there *was* interaction between technology policy and network governance and structure in Recife, that this interaction was *positive*, and that a large share of innovative firms participated in the network of innovators to develop their innovation activities. Based on the existence of state level policy to promote the emergence of a local network of innovators, and positive innovation performance among local firms, we can conclude that the promotion of local networks *has* increased the effectiveness of policy directed at improving local innovative performance.

The positive response of Recife local software firms to public policies aimed at promoting the formation of a network of innovators may be explained also by local firms need for complementary support (related to business or technical knowledge) to compensate for their backwardness in relation to competition in regional and national markets. This discussion reveals that the interactions between technology policy and network governance and structure in a developing country context may require specific consideration of the stage of development of both region and firms in order to achieve a more appropriate (consistent) and well-knit structure of interactions in which different ties are formed at different stages in the life cycle of innovation development. This issue is addressed in the discussion in Chapter 8 related to the Group B research questions introduced in Chapter 5.

CHAPTER 8 – DISCUSSION AND CONCLUSIONS

8.1 Introduction

The thesis investigated two regional software networks in Brazil, and especially their structure and governance (Chapters 4, 6 and 7), to provide evidence to answer the research questions introduced in Chapter 5, Section 5.2.

The research questions are in two groups: A and B. Chapters 6 and 7 respectively address the questions in Group A for the Campinas and Recife networks; the findings are summarised in this chapter which also addresses the questions in Group B through a comparison of the networks (Section 8.2). Section 8.3 identifies the main contributions of this thesis. Section 8.4 discusses the limitations of this research and Section 8.5 presents the implications for policy. Section 8.6 concludes with some suggestions for future research.

8.2 The Research Questions

This section highlights the findings in Chapters 6 and 7 (Section 8.2.1) and addresses the research questions in Group B (Section 8.2.2).

8.2.1 Revisiting the Group A research questions

Research Question A1

In considering government technology policy to promote firm innovation through networks in the case of the two Brazilian regions selected for analysis, how does regional level network governance and structure influence the effectiveness of policies supporting network creation in Brazil?

Chapter 2 outlined the relevance of government technology policy in the economy to assure higher levels social welfare, based on the definition of technology as a partial public good (Ergas, 1987; Mowery, 1995; Pavitt, 1987; Steinmueller, 2010). Chapter 2 also highlights the promotion of networks through different technology policy channels, including networks that enable firms to increase their possibility of learning-by-interaction, and acquiring new knowledge crucial for innovation (Lundvall, 1992a). Evidence on developed countries regional networks provides some confirmation of the relevance of networks for regional industrial growth and development and has encouraged developing countries to implement technology policies aimed at promoting network formation. Chapter 3 shows that Brazil was no exception, and introduced policies in the early 1990s, to foster the formation of regional software networks in different regions of the country (Stefanuto, 2004).

Chapter 4 discussed the cases of two of such networks, Campinas and Recife, and showed that they had different histories in the ICT industry, with implications for how the software industries developed in each of these networks following the implementation of the national policy programme.

Campinas is in the most economically developed Brazilian region and has benefited from national and state level policies to support regional industry development, mainly through the establishment of organisations that are directly related to research and scientific activities. Campinas has become the leading software region in Brazil. Government policy has played a role in this leadership position.

Recife, in contrast, is in an economically lagging Brazilian region, which is geographically distant from the most economically dynamic region, and has received less support from national policies directed to the development of the software industry. The lower level of national support has triggered the implementation by the government of Pernambuco state, where Recife is located, of state level technology policies directed towards the development of the local software industry and aimed at supporting economic catch-up by Recife and Pernambuco state (SECTMA, 2006).

The empirical findings discussed in Chapter 6 reveal that the network governance and structure of the Campinas software network of innovators has had a mixed influence on the effectiveness of government technology policies directed at firm innovation. This was indicated by the different results with regard to the *structural* embeddedness of the network compared to the results for *relational* embeddedness. The results for *structural* embeddedness indicate inconsistencies in a crucial sub-network, the skills sub-network, low engagement of technology sub-network actors, and low levels of interaction among local firms for innovation related activities. The results for *relational* embeddedness of the Campinas network reveal that most direct ties were tightly-connected ties, crucial for interactions aimed at knowledge exchange and learning among actors. These findings indicated that the *relational* embeddedness of the Campinas network governance and structure had a more positive influence than *structural* embeddedness, on technology policy effectiveness in relation to the promotion of firm-level innovation through network formation.

The empirical findings in Chapter 7 show that the influence of network governance and structure of the Recife software network of innovators was also mixed in terms of its effect on government technology policies for firm innovation. Again, the results for *structural* embeddedness of the network and *relational* embeddedness differ. The results for the *structural* embeddedness indicate some level of inconsistency in the skills sub-network (although this primarily is related to funding). They also show low level of engagement in the network of crucial actors such as university departments. The examination of ties with local technology sub-network actors showed that local firms had ties with only one local R&D organisation, although it is strongly related to its cluster of nodes. The level of interaction among local firms in Recife is shown also to be low. The results for *relational* embeddedness of network governance and structure are similar to the Campinas case for the tightness of ties, since most direct ties are tightly-connected, and as discussed above, a crucial feature of interactions aimed at knowledge exchange and learning among actors is tightly-connected ties. These findings indicate that the *relational* embeddedness of the Recife network's governance and structure had a more constructive influence than its *structural* embeddedness, in terms of the effectiveness of technology policy directed at firm-level innovation through the promotion of networks.

Although the historical and industrial trajectories of the Campinas and Recife software networks are different, these findings suggest some similarity between the regions with regard to network governance and structure. However, is the effectiveness of government policy in Brazil limited in relation to promoting the formation of networks? In both cases we found that structural embeddedness limited the effectiveness of government policy, especially in relation to the inconsistencies in the sub-networks. One of the main problems is the institutional path rigidity that is a feature of both networks, and indicates, as argued by Asheim and Gertler (2004), that the national context should be taken account of in an analysis of regions. The findings from this doctoral research suggest that reducing institutional rigidity must be a first step towards improving the effectiveness of government policy to promote network formation in Brazil.

Research Question A2

What, if any, is the responsiveness of network governance and structure to technology policy aimed at the promotion of networks in Brazil? Does government policy promotion of networks and efforts to control network structure increase the effectiveness of technology policy aimed at improving the innovative performance of Brazilian software firms?

The results in Chapter 6 show that the structure of the Campinas software network of innovators is fragmented, which suggests a low level of diffusion of formal interactions within the network. This finding suggests that the rate of response of Campinas software firms to government policies to promote network formation is low compared to the potential for interactions among firms, and between firms and other organisations. The results for the Campinas case show that there are limited interactions between technology policy and network governance and structure in Campinas, where firms show high levels of innovative performance and where a large share of innovative firms relies on internal sources for developing their innovation activities. Firms prefer to learn through experience rather than learning by interacting.

The results in Chapter 7 show that the level of diffusion of formal interactions is slightly higher in the Recife software network of innovators. Although the structure of the network is fragmented, we found signs of a trend towards a well-knit structure. In addition, key local actors keen to support the development and growth of Recife local software firms are active in the network, although not to a huge extent. The results for the Recife case show broader interaction between technology policy and network governance and structure in Recife (compared to Campinas), and a large share of innovative firms engaged in the network to develop their innovation activities. Based on the implementation of state policy to promote networks and the findings from this doctoral research, we can conclude that the promotion of local networks *has* increased the effectiveness of policy directed at improving local innovative performance.

8.2.2 Answering the Group B research questions

Research Question B1

Do network governance and structure have a consistent influence upon the innovative performance of Brazilian software firms set up in the two regions selected for analysis?

The innovative performance of the software firms embedded in the two networks investigated differs in absolute terms and in their nearness to the technological frontier. Chapter 5, Section 5.3.4, provides a discussion of the degree of novelty of commercialised innovations, in terms of newness to the firm, the national market or the international market.

The findings for firm-level innovation by firms embedded in the Campinas software network show that the level of innovation is comparatively higher in absolute terms and closer to the technology frontier. This is as expected because Campinas is the leading software region in Brazil. However, studies of systems of innovation claim that engagement in networks and network alignment are required for better innovative performance. The finding in this thesis show that innovative performance among the firms in both networks was better when firms were least engaged in the network, when network governance and structure were comparatively less aligned and their influence on technology policies directed at network formation to support innovation was more limited. In other words, the different levels of innovative performance of firms located in regions with different levels of socio-economic development, in a developing country context, such as the cases of Campinas and Recife, show different or inconsistent influence of network governance and structure on the effectiveness of government technology policy.

In addition, although network governance and structure in Recife was comparatively better aligned, innovation was mostly firm level (innovations new to the international markets were rare), which indicates that the region’s backwardness had an effect on the type of innovation being performed. This regional backwardness was a barrier to the conduct and diffusion of innovation, there was the predominance of one-off innovation projects and less re-use of previous innovative efforts/knowledge, with the result that firms embedded in Recife are continually re-inventing, which is constraining their possibilities for growth and economic returns.

Research Question B2

In assessing the effectiveness of technology policy in Brazil, are there relative differences in policy effects when comparing the two Brazilian regions analysed?

The findings provided evidence that in a context of backwardness, policies aimed at network formation are consistent with some positive effects, suggesting that backwardness is not a complete barrier. However, the Campinas network case does not provide clear evidence that network policies are causally responsible for the innovative performance of the firms in the network. The initial assumptions that network promotion policies would be positive in both cases (augmenting strengths and compensating for weaknesses) are not supported. There seems to be little evidence that the strengths among Campinas firms were augmented by policy as opposed to the organic growth of the relational embeddedness of the network. On the other hand, there is some evidence that network promotion policies play a role by compensating for weaknesses. Relational embeddedness is more remote from government policy because of the issues involved in the creation of ties. Structural embeddedness is closer to government policy in the sense that government has wider possibilities for action and rather more control over the results of policies implemented. The Recife case highlights the more positive interaction between structural and relational embeddedness compared to the Campinas case, suggesting that backwardness does not decrease the effectiveness of the policy – if anything it increases its importance.

The findings from the two case studies, and especially the results for the Campinas network, show that network promotion policies do not have such a positive effect on firm-level innovation performance as might be expected. Innovation performance tends not to depend on network governance and structure. Therefore, these findings challenge those who claim that networks and innovation are directly connected, that is, that better (more closely) connected firms will be more innovative. These claims, of course, are based largely on experience in developed countries. Nevertheless, these results were not as expected and suggest that network policies are unlikely to be effective substitutes for other elements of industrial policy (such as, procurement demand, support for research institutions, and direct support for the innovative efforts of firms). This leads to the conclusion that the relatively cheaper fostering of innovativeness through network promotion policies will not be as effective as the theory and experience in developed countries would suggest. Instead, it reinforces the argument that development and catching up are costly and long-term processes that require industrial policies complemented by and aligned to technology policies.

8.3 Contributions of the Thesis

This thesis was motivated by an interest in and concern for whether network promotion policies could be relied upon to contribute to the innovation effectiveness of firms involved in networks stimulated by those policies. From a careful review of the literature, we derived a series of general research questions that focus on the possible omissions or gaps in the consideration of factors that, in principle, might make a difference to the effectiveness of such policies. These general questions were operationalised for a situated study of two networks in Brazil, both of which were influenced by network promotion policies, and also had a number of contrasting features including differences in the levels of regional development in their situated contexts. This situated study has demonstrated that the issues identified in the general research questions are relevant to the situated cases examined and, therefore, should be taken account of in future policy related works on the effects of network promotion policies on innovation effectiveness. The following paragraphs provide a more complete explanation of the contributions of this thesis to the existing literature and to methods of policy analysis relevant for examining network promotion policies.

The first contribution relates to the need to include the *structural* and *relational* embeddedness of networks, within the same analytical framework. As discussed in Chapter 2, most studies on organisational networks concentrate on examining dyadic ties (relational embeddedness) (Provan and Kenis, 2008) and tend to ignore the institutional setting (structural embeddedness) (Grasenick *et al.*, 2008), which however is strongly related to controlling mechanisms within networks. This lack of attention to the institutional setting provided the basis for the first of the general research questions (question A1 and A2 in Chapter 1) and their specific operational implementation (in Chapter 5 and subsequent chapters).

This thesis captures the features of dyadic ties within the network, and the institutional settings that rule the ties among firms and between firms and other network organisations. Hence, it provides indicators that reflect the *quality* of relationships. This is a relevant area of investigation in the context of innovation systems in developing countries (Lundvall *et al*., 2009). Furthermore, it examines the structural features that go beyond the regional setting, for instance, by studying the consistency of the sub-networks in which national level organisations participate. The analytical framework contributes by bringing empirical evidence that relates to and supports Asheim and Gertler's (2004) claim that, although regions may differ (especially in large countries where regional disparities and path-rigidity are common) (Martin and Sunley, 2010), the national system of innovation in which they are embedded presents specific features that influence regional development and performance.

In addition, the thesis provides evidence that is specific to firms located in regional systems and groups such systems into 'families' based on commonalities, and provides a systematic comparison among regions, issues highlighted as in need of investigation by Lundvall *et al*. (2009b) and Padilla-Pérez *et al*. (2009). The thesis shows that although ties among network actors may be tightly-connected, there may be inconsistencies in sub-networks, and poor engagement of sub-networks (such as the technology and financial sub-networks) to support local technological development and innovation. The inconsistency in the role of sub-network support has been addressed conceptually by Bell and Pavitt, (1993), Cassiolato *et al.* (2003) and Lastres and Cassiolato (2001) as dysfunctional links within developing country innovation systems. The poor engagement of sub-networks is often described in the systems of innovation literature on developing countries as 'missing links' (Bell and Albu, 1999; Chaminade and Vang, 2008; Cimoli, 2002). The thesis advances the existing knowledge by clarifying these issues in a situated case, and demonstrating the utility of specific indicators for capturing these effects.

The second contribution of the thesis is methodological and also stems from the answers to the first set of general research questions (A1 and A2 in Chapter 1) as operationalised in Chapter 5 and subsequent chapters. By combining qualitative data and Social Network Analysis methods to study regional networks in Brazil, this research shows that conclusions may be drawn about how the engagement of actors in or their withdrawal from networks can influence their evolution. This is accomplished by analysing a visual representation of the network based on close examined data. This method serves also to highlight the actors that play bridging roles in the network.

Work on regional innovation in Brazil largely employs the Local Productive Arrangement (LPA) approach developed by Cassiolato and Lastres (1999). The LPA approach investigates three main issues: i) which markets are targeted by the 'arrangement'; ii) which governance mode is present in the 'arrangement' – that is, whether the decision power follows a hierarchical or network type structure; and iii) the relevance of the territory with regard to the presence of local capabilities. The main aim of LPA studies is to understand local industry performance and how territories can improve their competitiveness in a globalised economy (Lastres, 2007). This thesis has investigated governance and structure within networks and, based on visual representation, identified the following network features: i) tightness of ties; ii) how many and which firms are connected to organisations for innovation activities; iii) the structure of the network – that is, whether it is fragmented or well-knit; iv) the openness of the network; and v) which organisations (including firms) function as bridges in the network. Thus, this thesis research extends and elaborates the LPA framework, bringing greater specificity and rigour to this approach and opening possibilities for factors that might easily be omitted through adherence to an LPA framework approach to policy analysis.

This thesis contributes to our understanding of how economic and social forces influence network governance and structure, which is relevant for policy making (Pavitt, 1987). This understanding follows from the second set of general research questions (B1 and B2 as stated in Chapter 1 and made operational in Chapter 5 and subsequent chapters). As mentioned in Chapter 2, network governance and structure encompass issues such as whether the network is emergent or purposive, whether there are government efforts to promote networks (which may influence the type of network that is likely to emerge in a particular industry), level of openness of the network which influences its evolution, and the existence of network brokers that involve controlling mechanisms. Since different types of policy have proved important mechanisms to support public-private sector collaboration (Faulkner and Senker, 1995) and the establishment of ongoing networks of participants, the study of network infancy and evolution combined with studies on governance (understood as coordination) support the identification of elements that may contribute to the formulation of technology policies that address economic and industrial catching-up through the development and articulation of networks.

In addition, the analytical framework developed in this thesis to respond to the second general research questions (B1 and B2 as stated in Chapter 1 and made operational in Chapter 5 and subsequent chapters) allowed investigation of the interaction among different networks (identified here as sub-networks) with different purposes and membership based on different principles. This highlights the possibility that a given network may perform according to its stated principles or those principles related to recruiting members (here related to the consistency of networks) or, alternatively, that it may depart from these performance and/or membership principles (represented here as the inconsistency of networks). Hence, this level of analysis separates sub-networks according to purpose, providing empirical evidence that questions whether a mapping of the predominant purpose of networks or other conventional mapping techniques for networks is adequate to reveal their influence on innovation effectiveness. This thesis concludes that networks are more than a collection of dyadic relations between actors, a mapping that we find in empirical studies such as Cantner and Graf (2010) and Cantner *et al.* (2010), as well as in the system of innovation literature discussed in Chaminade and Vang (2008) and Lundvall *et al.* (2009b). The thesis advances knowledge on network alignment (von Tunzelmann, 2003) by making this concept operational.[306]

The third contribution of the thesis, also a response to the second general research questions (B 1 and 2 as stated in Chapter 1 and made operational in Chapter 5 and subsequent chapters) relates to the role played by networks with regard to firm-level innovativeness in a particular type of sector, that is, the high-technology sector, and a developing country context, that is, countries at an intermediate level of economic and social development, in which regional disparities can be substantial (Fagerberg and Srholec, 2008).[307] As discussed in Sections 2.2 and 2.4, the existing literature is undecided about when and how network structure and governance effects influence the effectiveness of policies aimed at promoting network formation and development. However, there are many studies of systems of innovation, including networks as a proxy for an investigation of the systemic links within systems, that

[306] Von Tunzelmann (2003: 46) defines network alignment as multiple networks that pull 'in similar directions to one another, even when their purposes differ' and 'orient their effectiveness towards attaining certain goals for the relevant systems' (von Tunzelmann, 2010: 4).
[307] Fagerberg and Srholec (2008) show that developing countries differ considerably in their science, research and innovation capabilities, openness to trade, production quality and standards, ICT infrastructure, education skills, quality of governance, social values and political systems.

argue that the engagement of firms in networks is relevant to improve firm-level innovation performance and economic catch-up, because networking increases the likelihood of firms' learning by interacting (Ahuja, 2000; Bresnahan *et al.*, 2001; Cantner and Graf, 2010; Castilla *et al.*, 2000; Cooke and de Laurentis, 2010; Dodgson *et al.*, 2008; Fuchs, 2010; Grasenick *et al.*, 2008; Herrigel, 1993; Kenney, 2000; Kim and Von Tunzelmann, 1998; Lazerson, 1993; Nohria, 1992; Okimoto, 1989; Saxenian, 1994; Uzzi, 1997).

The findings in this thesis show that high-technology (software) firms, in a country at an intermediate level of development (Brazil), which has large regional disparities (Lastres, 2007; Teixeira, 2008), engage differently in networks and show different innovative performance. When compared to the performance of networked firms in developed and other intermediate-level catching-up countries (such as in the studies mentioned above), Brazilian software firms embedded in regions with different structures (i.e. socio-economic and industrial development), show different engagement in networks and contradictory innovative performance. That is, we found that those firms less engaged in networking, the Campinas software firms, showed higher levels of innovative performance in absolute terms, and produce innovations that are closer to the technology frontier compared to regions where firms are more engaged in networking, that is, Recife software firms. However, although Recife showed comparatively lower innovation performance, networking in this region seems to have supported regional catching up. Therefore, a general technology policy prescription for the formation of networks as a mechanism to improve firm-level innovation and regional catching-up should not be adopted without very careful consideration of its intended effects; firm engagement in networks may not be a necessary condition for firm-level innovation improvements. Regional path-rigidity and contextual as well as network specific influences at infancy and during evolution of networks are also crucial elements in technology policy formulation.

8.4 Limitations of this Research

The thesis followed a multiple case study approach focusing on the investigation of network governance and structure and its interaction with government technology policy in a developing country context. The thesis examined two regional software networks in Brazil, and the findings highlight problem areas that have received little attention from other studies on innovation in developing countries. The findings on regional network governance and structure can be generalized, but there are some limitations related to other findings.

Firstly, the choice of a multiple case study limits the extent of the generalisability of the findings on network governance and structure to other regions and countries. The history of the two regions was a crucial element in analysis of how the networks emerged, evolved and their innovative performance. Within the time and other resources available to conduct a DPhil research project, two regions was practical in relation to data gathering for the thesis. Since it is impossible to know in advance what the structure and embeddedness of a network in a particular region will be, there is some risk of equivocal results if regions fail to exhibit all the expected relationships which then do not allow comparison of the magnitude of effects. This risk was realised in this research – the impact of network promotion policies was somewhat ambiguous between the two regions, which limits the strength of the conclusions. If a similar investigation of network governance and structure were to be implemented in other Brazilian regions or regions embedded in other developing counties, the findings might be less ambiguous.

Secondly, the choice of the software industry limits generalisation of the findings on network governance and structure. The technological activities performed by software firms may require the creation of external formal ties with specific types of actors and the nature of those ties might involve less mutual dependence (and loosely-connected ties) than might be the case where the economic performance of collaborators is more closely linked. The investigation of network governance and structure in industries that require the creation of different types of external formal ties than those applying to software development might produce different results from the ones in this study.

8.5 Implications for Policy

The findings from this thesis research have implications for policy. Firstly, they suggest that there is no one-size-fits-all network governance and structure, which is consistent with the findings from other studies on networks (e.g. Ahuja, 2000; Grasenick *et al.,* 2008). The institutional, cultural and economic settings may differ among regions, and policies aimed at promoting network formation to improve firms innovative performance should take into account that reproducing the network governance and structure of regions that have been successful may not be appropriate to other regions. As discussed, the findings from this thesis highlighted that network promotion policies on their own may not be an efficient mechanism for improved innovation performance and economic catch-up.

Secondly, the findings of inconsistency of sub-networks and poor engagement of organisations expected to play a primary role in fostering development and catch-up, or to be relevant throughout the life of the innovation development process, suggests that adjustments to the missions of these organisations are required, and policies aimed at the formation of networks should take those issues into account.

8.6 Questions for Future Research

This thesis has identified areas not covered here which could be tackled by future research on network governance and structure.

Firstly, the thesis was limited to the investigation of formal ties among innovative firms, and does not include informal ties or affiliations between firms and supporting organisations. Future research on network governance and structure could look at the relevance of informal ties and affiliations. This would enable a more comprehensive understanding of how a network might be supporting firm-level innovation activities in a developing country context. It would be a significantly larger research undertaking since the unit of analysis would shift from the network (where formal ties can be identified) to individuals or groups of individuals within the firm (where informal ties are likely to exist). Thus, it would be necessary to interview or survey a substantial proportion of actors engaged in a particular industry. This would ideally require and be most effective with state or industry association sponsorship.

Secondly, future research could gain from investigating other software regions in Brazil, or other industries within the same regions. It would be useful to bring additional evidence on the roles played by regional and industrial effects on the network governance and structure in which firms are embedded. This would illuminate issues regarding the co-evolution of network governance and structure and technological development in developing country regions. In terms of the *ex ante* choice made with respect to regions, the present study made the most reasonable choice given the time and resource limits. However, there are other regions in Brazil that could be included in a more extensive investigation, for instance Britto and Stallivieri (2010) highlight the existence of about 30 software Local Productive Arrangements in Brazil.

Thirdly, future research could examine network governance and structure in the regions investigated in this thesis, at some future time. This thesis examines the results well after initiation of central government promotion policies and rather soon after the implementation of state level policies. Examining these regions again after the accumulation of more experience with central and state level policies including the effects of backing away from or abandoning policies, would be informative. It would throw light on changes in network governance and structure and how such changes are influenced by government technology policies that aim at network formation as a mechanism to support firm-level innovation.

BIBLIOGRAPHY

Afonso, C. A., Brito, C. J. & Kneese, F. Q. S. (1999) Desenvolvimento Estratégico em Informática (DESI): Avaliação de Projeto *Número do Projeto: BRA/92/019.* Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Programa das Nações Unidas para o Desenvolvimento (PNUD).

Ahuja, G. (2000) 'Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study'. *Administrative Science Quarterly,* 45**,** 425-455.

Almeida, L. F. D. L. (2008) Competência Empreendedora de Relacionamento: Mobilizando o Capital Social no Processo de Absorção de Recursos *Departamento de Ciências Administrativas.* Recife, Universidade Federal do Pernambuco.

Araújo, E. E. R. D. & Meira, S. R. D. L. (2004) 'Inserção Competitiva do Brasil no Mercado Internacional de Software'. In Ministério Do Desenvolvimento, I. E. C. E., Instituto Euvaldo Lodi , Mdic/Sti (Ed.) *O Futuro da Indústria de Software: Perspectiva do Brasil, coletânea de artigos.* Brasília.

Araújo, S. V. (2011) Políticas para a Indústria de Software no Brasil: A Importância da Demanda *Escola de Administração.* Salvador, Universidade Federal da Bahia.

Araújo, S. V. & Teixeira, F. L. (2008) Estudo de Caso TECNOPUC: a Capacitação Como Chave para a Criação e Atração de Empresas in Tigre, P. B. (Ed.) *Desafios e Oportunidades para a Indústria de Software e Serviços na Argentina e no Brasil.* Salvador.

Arbix, G. (1997) 'A Câmara Banida'. In Arbix, G. & Zilbovicius, M. (Eds) *De JK a FHC, A Reinvenção dos Carros.* São Paulo, Scritta.

Asheim, B. T. & Gertler, M. S. (2004) 'The Geography of innovation: Regional Innovation Systems'. In Fagerberg, J., Mowery, D. C. & Nelson, R. R. (Eds) *The Oxford Handbook of Innovation.* New York, Oxford Universty Press.

Baldwin, R. E. (1969) 'The Case Against Infant-Industry Tariff Protection'. *Journal of Political Economy,* 77**,** 295.

Baumann, R. (2000) 'O Brasil nos anos 1990: Uma Economia em Transição'. In Baumann, R. (Ed.) *Brasil: Uma Década em Transição.* Rio de Janeiro, Editora Campus.

Bell, M. & Albu, M. (1999) 'Knowledge Systems and Technological Dynamism in Industrial Clusters in Developing Countries'. *World Development,* 27**,** 1715-1734.

Bell, M. & Pavitt, K. (1992) National Capabilities for Technological Accumulation: Evidence and Implications for Developing Countries *World Bank's Annual Conference on Development Economics.* Washington, D.C.

Bell, M. & Pavitt, K. (1993) 'Technological Accumulation and Industrial Growth: Contrasts Between Developed and Developing Countries'. *Industrial and Corporate Change,* 2**,** 157-210.

Bevir, M. (2009) *Key Concepts in Governance*, London, SAGE Publications.

Bevir, M. & Rhodes, R. A. W. (2001) A Decentered Theory of Governance: Rational Choice, Institutionalism, and Interpretation in Studies, I. O. G. (Ed.) *Working Paper.* UC Berkeley.

Bielschowsky, R. (1978) 'Notas Sobre a Questão da Autonomia Tecnológica na Indústria Brasileira'. In Suzigan, W. (Ed.) *Indústria: política, instituições e desenvolvimento.* Rio de Janeiro, IPEA/INPES.

BIS (2010) The Community Innovation Survey: United Kingdom London, Department for Business, Innovation and Skills.

Block, F. (1994) 'The Roles of the State in the Economy'. In Smelser, N. J. & Swedberg, R. (Eds) *The Handbook of Economic Sociology.* New York, Princeton University Press.

Bonelli, R. & Pinheiro, A. C. (2007) New Export Activities in Brazil: Comparative Advantage, Policy or Self-Discovery? *Instituto de Pesquisa Econômica Aplicada: Texto para Discussão.*

Boschma, R. (2005) Editorial: Role of Proximity in Interaction and Performance: Conceptual and Empirical Challenges *Regional Studies.* 39 ed.

Boschma, R. & Martin, R. (2010a) *The Handbook of Evolutionary Economic Geography,* Cheltenham, Edward Elgar.

Boschma, R. & Martin, R. (2010b) 'Introduction- The New Paradigm of Evolutionary Economic Geography'. In Boschma, R. & Martin, R. (Eds) *The Handbook of Evolutionary Economic Geography.* First ed. Cheltenham, Edward Elgar.

Boyer, R. (1997) 'The Variety and Unequal Performance of Really Existing Markets: Farewell to Doctor Pangloss?' In Hollingsworth, J. R. & Boyer, R. (Eds) *Contemporary Capitalism: the Embeddedness of Institutions.* Cambridge University Press.

Breschi, S. & Malerba, F. (1997) 'Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries '. In Edquist, C. (Ed.) *Systems of Innovation: Technologies, Institutions and Organizations.* London, Pinter.

Bresnahan, T., Gambardella, A. & Saxenian, A. (2001) '‘Old Economy’ Inputs for ‘New Economy’ Outcomes: Cluster Formation in the New Silicon Valleys'. *Industrial and Corporate Change,* 10**,** 835-860.

Britto, J., Cassiolato, J. E. & Stallivieri, F. (2007) Sectoral System of Innovation and Patterns of Specialization in the Software Industry: a Comparative Analysis of Brazil, China and Russia *Globelics Russia 2007 - 5th International Conference.* Russia.

Britto, J. & Stallivieri, F. (2010) 'Inovação, Cooperação e Aprendizado no Setor de Software no Brasil: Análise Exploratória Baseada no Conceito de Arranjos Produtivos Locais (APLs)'. *Economia e Sociedade,* 19**,** 315-358.

Brodley, J. F. (1990) 'Antitrust Law and Innovation Cooperation'. *The Journal of Economic Perspectives,* 4**,** 97-112.

Brooks Jr., F. P. (1995) *The Mythical Man-Month: Essays on Software Engineering,* Addison-Wesley Publishing Company.

Burt, R. S. (1992) *Structural Holes: The Social Structure of Competition*, Harvard University Press.

Callon, M. (1999) 'Actor-netwrok Theory - The Market Test'. In Law, J. & Hassard, J. (Eds) *Actor Network Theory and After.* Oxford, Blackwell.

Campos, R. R., Nicolau, J. A. & Cário, S. A. F. (1998) O Cluster da Indústria Cerâmica de Revestimento em Santa Catarina: Um Caso de Siatema Local de Inovação. In Globalização e Inovação Localizada: Experiências de Sistemas Locais no Âmbito do Mercosul e Proposições de Políticas de C&T. Nota Técnica 29/99. Rio de Janeiro, Intituto de Economia - Universidade Federal do Rio de Janeiro.

Cantner, U. & Graf, H. (2010) 'Growth, Development and Structural Change of Innovator Networks: the Case of Jena'. In Boschma, R. & Martin, R. (Eds) *The Handbook of Evolutionary Economic Geography.* Cheltenham, Edward Elgad.

Cantner, U., Meder, A. & Ter Wal, A. L. J. (2010) 'Innovator networks and regional knowledge base'. *Technovation,* 30**,** 496-507.

CAPES (2010) Período de Avaliação 2007 a 2009 *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior- Avaliação Trienal 2010.* Brasília, Ministério da Educação - Brasil.

Carneiro, R. M. (2002) *Desenvolvimento em Crise: A Economia Brasileira no Último Quarto do Século XX* São Paulo, Fundação da Editora UNESP

Cassiolato, J. E. & Lastres, H. M. M. (1999) *Globalização e Inovação Localizada: Esperiências de Sistemas Locais no Mercosul*, Brasília, Ministério da Ciência e Tecnologia, Brasil.

Cassiolato, J. E. & Lastres, H. M. M. (2003) 'O Foco em Arranjos Produtivos e Inovativos Locais de Micro e Pequenas Empresas'. In Lastres, H. M. M., Cassiolato, J. E. & Maciel, M. L. (Eds) *Pequena Empresa: Cooperação e Desenvolvimento Local.* Rio de Janeiro, Relume Dumará.

Cassiolato, J. E., Lastres, H. M. M. & Maciel, M. L. (2003) *Systems of Innovation and Development: Evidence from Brazil*, Cheltenham, Edward Elgar.

Cassiolato, J. E., Lastres, H. M. M. & Stallivieri (2008a) *Arranjos Produtivos Locais: uma Alternativa para o Desenvolvimento,* Rio de Janeiro, E-papers Serviços Editoriais Ltda.

Cassiolato, J. E., Lastres, H. M. M. & Stallivieri, F. (2008b) *Introdução: Políticas Estaduais e Mobilização de Atores Políticos em Arranjos Produtivos e Inovativos Locais*, Rio de Janeiro, E-papers Serviços Editoriais Ltda.

Castilho, M. D. R. & Luporini, V. (2010) A Elasticidade-renda do Comércio Regional de Produtos Manufaturados *Textos para Discussão CEPAL-IPEA, 18.* Brasília, CEPAL - IPEA.

Castilla, E., Hwang, H., Granovetter, E. & Granovetter, M. (2000) 'Social Networks in Silicon Valley'. In Lee, C.-M., Miller, W. F., Hancock, M. G. & Rowen, H. S. (Eds) *The Silicon Valley Edge.* Stanford University Press.

Chaminade, C. & Vang, J. (2008) 'Globalisation of Knowledge Production and Regional Innovation Policy: Supporting Specialized Hubs in the Bangalore Software Industry'. *Research Policy,* 37**,** 1684-1696.

Chang, H.-J. (1994) *The Political Economy of Industrial Policy,* London, The Macmillan Press Ltd.

Chang, H.-J. & Rowthorn, R. (1995) 'Role of the State in Economic Change: Entrepreneurship and Conflict Management'. In Chang, H.-J. & Rowthorn, R. (Eds) *The Role of the State in Economic Change.* Oxford, Clarendon Press.

Cimoli, M. (2002) 'Networks, Market Structures and Economic Shocks: the Structural Changes of Innovation Systems in Latin America'. *LEM Working Paper Series,* 2003**,** 1-34.

Cohen, W. M. & Levinthal, D. A. (1990) 'Absorptive Capacity: A New Perspective on Learning and Innovation'. *Administrative Science Quarterly,* 35**,** 128-152.

Cooke, P. (2001) 'Regional Innovation Systems, Clusters, and the Knowledge Economy'. *Industrial and Corporate Change,* 10**,** 945-974.

Cooke, P. & De Laurentis, C. (2010) 'Evolutionary Economic Geography: Regional Systems of Innovation and High-tech Clusters'. In Boschma, R. & Martin, R. (Eds) *The Handbook of Evolutionary Economic Geography.* Cheltenham, Edward Elgad.

Corder, S. M. (2004) Financiamentos e Incentivos ao Sistema de Ciência, Tecnologia e Inovação no Brasil: Quadro Atual e Perspectivas *Departamento de Política Científica e Tecnológica.* Campinas, Universidade Esatdual de Campinas.

Costa, I. (1998) O Setor de Autopeças no Brasil: Desafios e Mudanças na Década de Noventa *Departamento de Política Científica e Tecnológica.* Campinas, State University of Campinas.

Costa, I. & Queiroz, S. R. R. D. (2002) 'Foreign Direct Investment and Technological Capabilities in Brazilian Industry'. *Research Policy***,** 1-13.

Cusumano, M. A. & Selby, R. W. (1995) *Microsoft Secrets: How the World's Most Powerful Software Company Creates Technology, Shapes Markets, and Manages People,* London, HarperCollinsBusiness.

Da Silva, F. Q. B. (2008) A City and its Science Park: Building a Local Innovation System for Urban and Economic Development *XXV IASP World Conference.* Gauteng, South Africa.

Dagnino, R. & Velho, L. (1998) 'A Relação Universidade-Indústria-Governo em Países Periféricos: o caso da Universidade Estadual de Campinas'. In Dagnino, R. & Thomas, H. (Eds) *A Pesquisa Universitária na América Latina e a Vinculação Universidade-Empresa.* Chapecó, Editora da Unochapecó.

Dahlman, C. J. & Frischtak, C. R. (1993) 'National Systems Supporting Technical Advance in Industry: the Brazilian Experience'. In Nelson, R. R. (Ed.) *National Innovation Systems: a Comparative Analysis.* New York, Oxford University Press.

Dantas, E. (2006) The Development of Knowledge Networks in Latecomers Innovation Systems: The Case of Petrobrás in the Brazilian Offshore Oil

Industry *SPRU - Science and Technology Policy Research.* Brighton, University of Sussex.

Dantas, E. & Bell, M. (2009) 'Latecomer Firms and the Emergence and Development of Knowledge Networks: The Case of Petrobras in Brazil'. *Research Policy,* 38**,** 829-844.

Dasgupta, P. (1987) 'The economic theory of technology policy: an introduction'. In Dasgupta, P. (Ed.) *Economic Policy and Technological Performance.* Cambridge, Cambridge University Press.

David, P. A. (1994) 'Why are institutions the carriers of history?: Path dependence and the evolution of conventions, organizations and institutions'. *Structural Change and Economic Dynamics,* 5**,** 205-220.

David, P. A. & Keely, L. C. (2003) 'The Economics of Scientific Research Coalitions: Collaborative Network Formation in the Presence of Multiple Funding Agencies '. In Geuna, A., Salter, A., J. & Steinmueller, W. E. (Eds) *Science and Innovation: Rethinking the Rationales for Funding and Governance.* Cheltenham, Edward Elgar.

De Campos, A. L. S. (2006) University-Industry Links in Late-Industrializing Countries: A Study of Unilever Brazil *Science and Technology Policy Research - SPRU.* Brighton, University of Sussex.

Debreson, C. & Amese, F. (1991) 'Networks of Innovators: A Review and Introduction to the Issue'. *Research Policy,* 20**,** 363-379.

Dodgson, M., Mathews, J., Kastelle, T. & Hu, M.-C. (2008) 'The Evolving Nature of Taiwan's National Innovation System: The Case of Biotechnology Innovation Networks'. *Research Policy,* 37**,** 430-445.

Dohse, D. (2000) 'Technology policy and the regions -- the case of the BioRegio contest'. *Research Policy,* 29**,** 1111-1133.

Dosi, G. (1982) 'Technological Paradigms and Technological Trajectories : A Suggested Interpretation of the Determinants and Directions of Technical Change'. *Research Policy,* 11**,** 147-162.

Downs, A. (1964) 'Inside Bureaucracy'. *RAND Corporation Paper Series,* P-2963.

Duarte, L. S. (2003) Caracterização da Inovação Tecnológica no Setor de Software de Gestão Integrada: estudos de casos nas emrpesas de base tecnológica do Estado de São Paulo *Instituto de Economia.* Campinas Universidade Estadual de Campinas.

Edquist, C. (2004) 'Systems of Innovation: Perspectives and Challenges'. In Fagerberg, J., Mowery, D. C. & Nelson, R. R. (Eds) *The Oxford Handbook of Innovation.* New York, Oxford Universty Press.

Ergas, H. (1987) 'The importance of technology policy'. In Dasgupta, P. & Stoneman, P. (Eds) *Economic Policy and Technological Performance.* Cambridge, Cambridge University Press.

Evans, P. B. (1995) *Embedded Autonomy*, Princeton University Press.

FACEPE (2006) FACEPE em Números (2000-2005) Recife, Governo do Estado do Pernambuco.

Fagerberg, J. & Srholec, M. (2008) 'National Innovation Systems, Capabilities and Economic Development'. *Research Policy,* 37**,** 1417-1435.

FAPESP (2008) Relatório de Atividades 2008 São Paulo, Fundação de Amparo à Pesquisa do Estado de São Paulo.

FAPESP (2009) Relatório de Atividades 2009 São Paulo, Fundação de Amparo à Pesquisa do Estado de São Paulo.

Faulkner, W. & Senker, J. (1995) *Knowledge Frontiers: Public Sector Research and Industrial Innovation in Biotechnology, Engineering Ceramics, and Parallel Computing*, Oxford, Clarendon Press.

Freeman, C. (1974) *The Economics of Industrial Innovation,* Harmondsworth, Penguin.

Freeman, C. (1987) *Technology and economic performance: lessons from Japan,* London, Pinter Publishers.

Freeman, C. (1991) 'Networks of innovators: A synthesis of research issues'. *Research Policy,* 20**,** 499-514.

Freeman, C. (2002) 'Continental, National and Sub-national Innovation Systems - Complementarity and Economic Growth'. *Research Policy,* 31**,** 191-211.

Freeman, C. & Soete, L. (1997) *The Economics of Industrial Innovation*, Pinter.

Friedman, M. (2002) *Capitalism and Freedom*, The University of Chicago Press.

Friedman, T. L. (2005) *The World Is Flat: A Brief History of the Twenty-first Century,* Farrar, Straus & Giroux

Fuchs, E. R. H. (2010) 'Rethinking the Role of the State in Technology Development: DARPA and the Case for Embedded Network Governance'. *Research Policy,* 39**,** 1133-1147.

Gaio, F. J. (1992) 'Software strategies for developing countries: lessons from the international and Brazilian experiences'. In Schmitz, H. & Cassiolato, J. E. (Eds) *Hi-tech for industrial development: Lessons from the Brazilian experience in electronics and automation.* London, Routledge.

Garcia, R. (2000) Experiências de Clusters em Setores de Alta Tecnologia: o Caso da Região de Campinas, São Paulo *V Encontro Nacional de Economia Política.* Fortaleza, Ceará, Sociedade Brasileira de Economia Política.

Garcia, R. & Roselino, J. E. (2004) 'Uma Avaliação da Lei de Informática e de seus Resultados como Instrumento Indutor de Desenvolvimento Tecnológico e Industrial'. *Gestão e Produção,* 11**,** 177-185.

Garcia, R. & Souza, M. C. (1999) 'Sistemas Locais de Inovacao em Sao Paulo'. In Cassiolato, J. E. & Lastres, H. M. M. (Eds) *Globalizacao e Inovacao Localizada: Experiencias de Sistemas Locais no Mercosul.* Brasilia, IBICT/MCT.

Giuliani, E. (2010) 'Clusters, Networks and Economic Development: an Evolutionary Economics Perspective'. In Boschma, R. & Martin, R. (Eds) *The Handbook of Evolutionary Economic Geography*. Cheltenham, Edward Elgad.

Grabher, G. (1993) 'The weakness of strong ties: the lock-in of regional development in the Ruhr area'. In Grabher, G. (Ed.) *The Embbeded Firm: on the Socioeconomics of industrial networks.* London, Routledge.

Grabher, G. & Powell, W. W. (2004) 'Introduction'. In Grabher, G. & Powell, W. W. (Eds) *Networks.* Cheltenham, Edward Elgar.

Granovetter, M. (1973) 'The Strength of Weak Ties'. *American Journal of Sociology,* 78**,** 1360-1380.

Granovetter, M. (1985) 'Economic Action and Social Structure: The Problem of Embeddedness'. *The American Journal of Sociology,* 91**,** 481-510.

Granovetter, M. (1992) 'Problems of Explanation in Economic Sociology'. In Nohria, N. & Eccles, R. G. (Eds) *Networks and Organizations: Structure, Form, and Action.* Boston, Harvard Business School Press.

Granovetter, M. (1994) 'Business Groups'. In Smelser, N. J. & Swedberg, R. (Eds) *The Handbook of Economic Sociology.* New York, Princeton University Press.

Grasenick, K., Wagner, G. & Zumbusch, K. (2008) 'Trapped in a Net: Network Analysis for Network Governance'. *VINE: The Journal of Information and Management Systems,* 38**,** 296-314.

Grimaldi, R. & Torrisi, S. (2001) 'Codified-tacit and general-specific knowledge in the division of labour among firms: A study of the software industry'. *Research Policy,* 30**,** 1425-1442.

Håkanson, L. (2005) 'Epistemic Communities and Cluster Dynamics: On the Role of Knowledge in Industrial Districts'. *Industry & Innovation,* 12**,** 433-463.

Heeks, R., Krishna, S., Nicholson, B. & Sahay, S. (2001) 'Synching or Sinking: Global Software Outsourcing Relationships'. *IEEE Software,* 18**,** 54-60.

Herrigel, G. B. (1993) 'Power and the redefinition of industrial districts: the case of Baden-Württemberg'. In Grabher, G. (Ed.) *The Embbeded Firm: on the Socioeconomics of industrial networks.* London, Routledge.

Howells, J. (1999) 'Regional Systems of Innovation?' In Archibugi, D., Howells, J. & Michie, J. (Eds) *Innovation Policy in a Global Economy.* Cambridge, Cambridge University Press.

IBGE (2008) Produto Interno Bruto Brasília, Instituto Brasileiro de Geografia e Estatística.

IBGE (2009) 'Contas Nacionais Trimestrais-Indicadores de Volume e Valores Correntes'.

IBGE (2010a) Sinopse do Censo Demográfico 2010: Tabela 1.4 - População nos Censos Demográficos, segundo as Grandes Regiões e as Unidades da Federação - 1872/2010 Brasília, Instituto Brasileiro de Geografia e Estatística.

IBGE (2010b) Sinopse do Censo Demográfico 2010: Tabela 1.5 - Distribuição percentual da população nos Censos Demográficos, segundo as Grandes Regiões e as Unidades da Federação - 1872/2010 Brasília, Instituto Brasileiro de Geografia e Estatística.

IBGE (2010c) Sinopse do Censo Demográfico 2010: Tabela 1.14 - Municípios com População Residente Superior a 50 000 Pessoas, em Ordem Decrescente de População Residente - 2010 Brasília, Instituto Brasileiro de Geografia e Estatística.

INEP (2009) Resumo Técnico: Censo da Educação Superior de 2009 Brasília, Ministério da Educação.

IPARDES (2006) Arranjo produtivo local de software de Londrina: estudo de caso Curitiba, Instituto Paranaense de Desenvolvimento Econômico e Social.

Jones, C., Hesterly, W. S. & Borgatti, S. P. (1997) 'A General Theory of Network Governance: Exchange Conditions and Social Mechanisms'. *Academy of Management Review,* 22**,** 911-945.

Jorde, T. M. & Teece, D. J. (1989) 'Competition and Cooperation: Striking the Right Balance'. *California Management Review,* 31**,** 25-37.

Kaufmann, D., Kraay, A. & Mastruzzi, M. (2010) The Worldwide Governance Indicators: Methodology and Analytical Issues *World Bank Policy Research - Working Paper No. 5430.*

Kenney, M. (2000) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region,* Stanford University Press.

Kim, S.-R. & Von Tunzelmann, N. (1998) Aligning internal and external networks: Taiwan's specialization in IT *SPRU Electronic Working Paper Series.*

Krueger, A. O. (1991) 'Government Failures in Development'. *The National Bureau of Economic Research, Working Paper***,** 1-26.

Krueger, A. O. (1997) 'Trade Policy and Economic Development: How We Learn'. *The American Economic Review,* 87**,** 1-22.

Lastres, H. M. M. (2007) Avaliação das políticas de promoção de arranjos produtivos locais no Brasil e proposições de ações Brasília, Centro de Gestão e Estudos Estratégicos.

Lastres, H. M. M. & Cassiolato, J. E. (2001) 'Globalização e os Sistemas de Inovação no Mercosul nos anos 90: Implicações para Políticas'. In Guimarães, N. A. & Martin, S. (Eds) *Competitividade e Desenvolvimento: Atores e Instituições Locais.* São Paulo, Editora SENAC São Paulo.

Lazerson, M. (1993) 'Factory or putting-out? Knitting networks in Modena'. In Grabher, G. (Ed.) *The Embbeded Firm: on the Socioeconomics of industrial networks.* London, Routledge.

List, F. (1841) *The National System of Political Economy,* London, Longman.

Lundvall, B.-Å. (1992a) 'Introduction'. In Lundvall, B.-Ä. (Ed.) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London, Pinter Publisher.

Lundvall, B.-Å. (1992b) 'User-Producer Relationships, National Systems of Innovation and Internationalisation'. In Lundvall, B.-Ä. (Ed.) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London, Pinter Publisher.

Lundvall, B.-Å. & Borrás, S. (2005) 'Science, Technology and Innovation Policy'. In Fagerberg, J., Mowery, D. C. & Nelson, R. R. (Eds) *The Oxford Handbook of Innovation.* New York, Oxford University Press.

Lundvall, B.-Å., Joseph, K. J., Chaminade, C. & Vang, J. (2009a) *Handbook of Innovation Systems and Developing Countries,* Cheltenham, Edward Elgar.

Lundvall, B.-Å., Vang, J., Joseph, K. J. & Chaminade, C. (2009b) 'Innovation System Research and Developing Countries'. In Lundvall, B.-Å., Joseph, K. J., Chaminade, C. & Vang, J. (Eds) *Handbook of Innovation Systems and Developing Countries.* Cheltenham, Edward Elgar.

Machado, S. A. (2003) Dinâmica dos arranjos produtivos locais: um estudo de caso em Santa Gertrudes, a nova capital da cerâmica brasileira *Escola Politécnica.* São Paulo, Universidade de São Paulo.

Malerba, F. (2002) 'Sectoral Systems of Innovation and Production'. *Research Policy,* 31**,** 247-264.

Malerba, F. (2004) 'Sectoral Systems of Innovation: Basic Concepts'. In Malerba, F. (Ed.) *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe.* Cambridge, Cambridge University Press.

Mani, S. (2001) Government, Innovation and Technology Policy, an Analisys of the Brazilian Experience during the 1990s *Discussion Paper Series.* 2001-11 ed. Maastricht, Institute for New Technologies (INTECH), United Nations University.

Marinho, C. (2008) O Porto Digital do Recife: Lições Aprendidas com a Implementação Público-privada de um APL de TIC, Porto Marinho.

Marinho, C. & Simis, E. (2007) Estudo de caso do Consórcio ActMinds Recife, Cooperação Técnica BID/FUMIN/SOFTEX. Programa de apoio à competitividade das pequenas e médias empresas de software.

Markusen, A. (1996) 'Sticky Places in Slippery Space: A Typology of Industrial Districts'. *Economic Geography,* 72**,** 293-313.

Markwald, R. A. (2001) O Impacto da Abertura Comercial Sobre a Indústria Brasileira: Balanço de uma Década *Revista Brasileira de Comércio Exterior.* Julho-Setembro ed. Rio de Janeiro.

Martin, R. & Sunley, P. (2006) 'Path Dependence and Regional Economic Evolution'. *Journal of Economic Geography,* 6**,** 395-437.

Martin, R. & Sunley, P. (2010) 'The place of path dependence in an evolutionary perspective on the economic landscape'. In Boschma, R. & Martin, R. (Eds) *The Handbook of Evolutionary Economic Geography.* Cheltenham, Edward Elgad.

MCT (2011) Plano de Ação em CTI - Principais Resultados e avanços 2007-2010.

MIT-Softex (2002) A Indústria de Software no Brasil - 2002: Fortalecendo a Economia do Conhecimento Campinas, Massachussets Institute of Technology and Sociedade Softex.

Morel, R. L. D. M. (1979) *Ciência e Estado no Brasil: a política científica no Brasil,* São Paulo, TAO.

Mowery, D. C. (1995) 'The Practice of Technology Policy'. In Stoneman, P. (Ed.) *Handbook of the Economics of Innovation and Technological Change.* Oxford, Blackwell Publisher.

Mowery, D. C. & Langlois, R. N. (1996) 'Spinning off and Spinning on (?): the Federal Government Role in the Development of the US Computer Software Industry'. *Research Policy,* 25**,** 947-966.

Nelson, R. R. (1977) *The Moon and the Ghetto: an Essay on Public Policy Analysis,* New York, W. W. Norton & Company.

Nelson, R. R. (1993) *National Innovation Systems: a Comparative Analysis,* New York, Oxford University Press.

Nelson, R. R. & Rosenberg, N. (1993) 'Technical Innovation and National Systems'. In Nelson, R. R. (Ed.) *National Innovation Systems.* New York, Oxford University Press.

Nelson, R. R. & Winter, S. G. (1982) *An Evolutionary Theory of Economic Change,* Harvard University Press.

NGPD (2009a) Projetos e Parcerias para Inovação: Ações para o Fortalecimento do Setor de TIC em Pernambuco Recife, Núcleo de Gestão do Porto Digital.

NGPD (2009b) Relatório de Acompanhamento do Plano Estratégico do Porto Digital 2006-2009 Recife, Núcleo de Gestão do Porto Digital.

Nohria, N. (1992) 'Information and Search in the Creation of New Business Ventures: The Case of the 128 Venture Group'. In Nohria, N. & Eccles, R. G. (Eds) *Networks and Organizations: Structure, Form, and Action.* Boston, Harvard Business School Press.

NSF (2010) Science and Engineering Indicators Arlington, National Science Foundation.

OECD (2005) *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, Paris, OECD: Organization for Economic Co-Operation and Development.

Okimoto, D. I. (1989) *Between MITI and the Market: Japanese Industrial Policy for High Technology*, Stanford University Press.

Oliveira, N. N. P. (2004) Do ITA à EMBRAER: a Idéia de Progresso dos Militares Brasileiros para a Indústria Aeronáutica. *Anais do XVII Encontro Regional de História – O Lugar da História.* Campinas, São Paulo, Brazil.

Oliveira, S. D. C. (2008) Sobre a Interacao Universidade-Empresa no Desenvolvimento de Software: Um Estudo de Caso no Recife *Instituto de Economia.* Rio de Janeiro, Rio de Janeiro Federal University.

Pacheco, C. A. (2007) As reformas da política nacional de ciência, tecnologia e inovação no Brasil (1999-2002) Santiago do Chile, Comissão Econômica para a América Latina-CEPAL.

Pacheco, C. A. & Corder, S. (2009) Mapeamento institucional e de medidas de política com impacto sobre a inovação produtiva e a diversificação das exportações Santiago do Chile, Comissão Econômica para a América Latina e o Caribe (CEPAL).

Padilla-Pérez, R., Vang, J. & Chaminade, C. (2009) 'Regional innovation systems in developing countries: integrating micro and meso-level capabilities'. In Lundvall, B.-Å., Joseph, K. J., Chaminade, C. & Vang, J. (Eds) *Handbook of Innovation Systems and Developing Countries.* Cheltenham, Edward Elgar.

Patel, P. & Pavitt, K. (1994) 'National Innovation Systems: Why They Are Important, And How They Might Be Measured And Compared'. *Economics of Innovation and New Technology,* 3**,** 77 - 95.

Pavitt, K. (1984) 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory'. *Research Policy,* 13**,** 343-373.

Pavitt, K. (1987) 'The Objectives of Technology Policy'. *Science and Public Policy,* 14**,** 182-188.

Pavitt, K. (1998) 'Technologies, Products and Organization in the Innovating Firm: What Adam Smith Tells Us and Joseph Schumpeter Doesn't'. *Industrial and Corporate Change,* 7**,** 433-452.

Penrose, E. (1959) *The Theory of the Growth of the Firm,* London, Basic Blackwell.

Pérez, C. (2001) 'Technological Change and Opportunities for Development as a Moving Target'. *CEPAL Review,* 75**,** 109-130.

Pérez, C. (2008) A Vision for Latin America: a resource-based strategy for technological dynamism and social inclusion Santiago do Chile, ECLAC

Perini, F. (2009) Organising Innovation Between Multinational Companies and Innovation Systems: The Brazilian ICT Sector in the Late 1990s and Early 2000s *Science and Technology Policy Research - SPRU.* Brighton, University of Sussex.

Pietrobelli, C. & Rabellotti, R. (2009) 'The Global Dimension of Innovation Systems: Linking Innovation Systems and Global Value Chains'. In Lundvall, B.-Å., Joseph, K. J., Chaminade, C. & Vang, J. (Eds) *Handbook of Innovation Systems and Developing Countries.* Cheltenham, Edward Elgar.

Pintec (2010a) Pesquisa de Inovação Tecnológica: Notas Técnicas Rio de Janeiro, Instituto Brasileiro de Geografia e Estatística-IBGE.

Pintec (2010b) Pesquisa de Inovação Tecnológica: Publicação Completa Rio de Janeiro, Instituto Brasileiro de Geografia e Estatística-IBGE.

Porto Digital (2003) Relatório Anual Recife, Núcleo de Gestão do Porto Digital.

Powell, W. W. (1990) 'Neither Market Nor Hierarchy: Network Forms of Organization '. *Research in Organizational Behavior,* 112**,** 395-336.

Powell, W. W. & Grodal, S. (2005) 'Networks of Innovators'. In Fagerberg, J., Mowery, D. C. & Nelson, R. R. (Eds) *The Oxford Handbook of Innovation.* New York, Oxford University Press.

Provan, K. G., Huang, K. & Milward, H. B. (2009) 'The Evolution of Structural Embeddedness and Organizational Social Outcomes in a Centrally Governed Health and Human Services Network'. *Journal of Public Administration Research Theory,* 19**,** 873-893.

Provan, K. G. & Kenis, P. (2008) 'Modes of Network Governance: Structure, Management, and Effectiveness'. *Journal of Public Administration Research Theory,* 18**,** 229-252.

Ramirez, M. & Dickenson, P. (2010) 'Gatekeepers, Knowledge Brokers and Inter-firm Knowledge Transfer in Beijing's Zhongguancun Science Park'. *International Journal of Innovation Management,* 14**,** 93-122.

Redesist (2005) Glossário de Arranjos e Sistemas Produtivos e Inovativos Locais in Lastres, H. M. M. & Cassiolato, J. E. (Eds) Rio de Janeiro, http://redesist.ie.ufrj.br/glossario.php.

Rhodes, R. A. W. (2007) 'Understanding Governance: Ten Year On'. *Organization Studies,* 28**,** 1243-1264.

Ritz, M. R. D. C. (2008) Institutos Privados de P&D no Brasil: uma Análise do Setor de Tecnologias da Informação e Comunicação *Departamento de Política Científica e Tecnológica.* Campinas, Universidade Estadual de Campinas.

Rodrik, D. (1993) Trade and Industrial Policy Reform in Developing Countries: a Review of Recent Theory and Evidence *NBER Working Paper Series.*

Roselino, J. E. (2006) A Indústria de Software: o “Modelo Brasileiro” em Perspectiva Comparada *Instituto de Economia.* Campinas, Universidade Estadual de Campinas.

Rothwell, R. & Zegveld, W. (1982) *Innovation and the Small and Medium Sized Firm: Their role in employment and in economic change,* London, Francis Pinter.

Rousseva, R. (2008) 'Identifying Technological Capabilities with Different Degrees of Coherence: The Challenge to Achieve High Technological Sophistication in Latecomer Software Companies (Based on the Bulgarian Case)'. *Technological Forecasting and Social Change,* 75**,** 1007-1031.

Sagasti, F. (2003) The Sisyphus Challenge: Knowledge, Innovation and the Human Condition in the 21st Century, FORO Nacional / International Lima, Peru.

Salerno, M. S., Marx, R., Zilbovicius, M., Graziadio, T., Dias, A. V. C., Muniz, S. T. G., Garcia, R., Lima, J. C. D. S., Iveson, S., Hotta, M. A. & Soares, R. (2002) A Nova Configuração da Cadeia Automotiva Brasileira. Pesquisa desenvolvida junto ao BNDES, Escola Politécnica da Universidade de São Paulo. Departamento de Engenharia da Produção. Grupo de Estudos de Trabalho, Tecnologia e Organização.

Salter, A., J. & Martin, B. R. (2001) 'The Economic Benefits of Publicly Funded Basic Research: a Critical Review'. *Research Policy,* 30**,** 509-532.

Saxenian, A. (1990) 'Regional Networks and the Resurgence of Silicon Valley'. *California Management Review,* 33**,** 89-112.

Saxenian, A. (1994) *Regional advantage: culture and competition in Silicon Valley and Route 128,* Cambridge, Massachusetts, Harvard University Press.

Scott, J. (1991) *Social Network Analysis: a Handbook*, London, Sage Publications.

SECTMA (2006) Marcos de uma Geração Voltada para o Futuro: Cência, Tecnologia e Meio Ambiente em Pernambuco 1999-2006 Recife, Secretaria de Cência, Tecnologia e Meio Ambiente.

Semlinger, K. (2008) 'Cooperation and competition in network governance: regional networks in a globalised economy'. *Entrepreneurship & Regional Development,* 20**,** 547-560.

Shapiro, C. & Varian, H. R. (1999) *Information Rules: a Strategic Guide to the Network Economy,* Boston, Harward Business School Press.

Shapiro, C. & Willig, R. D. (1990) 'On the Antitrust Treatment of Production Joint Ventures'. *Journal of Economic Perspectives,* 4**,** 113-130.

Softex (2005) Banking Automation: Brazil in the International Scenario in Digital, S.-O. (Ed.) Campinas, Sociedade Softex.

Stefanuto, G. N. (2004) O Programa SOFTEX e a Industria de Software no Brasil *Departamento de Politica Cientifica e Tecnologica.* Campinas, Universidade Estadual de Campinas.

Steinmueller, W. E. (1996) 'The U.S. Software Industry: an analysis and interpretive history'. In Mowery, D. C. (Ed.) *The International Computer Software Industry: a comparative study of industry evolution and structure.* New York, Oxford University Press.

Steinmueller, W. E. (2001) 'ICTs and the possibilities for leapfrogging by developing countries'. *International Labour Review,* 140**,** 193-210.

Steinmueller, W. E. (2004) 'The European Software Sectoral System of Innovation'. In Malerba, F. (Ed.) *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe.* Cambridge, Cambridge University Press.

Steinmueller, W. E. (2010) 'Economics of Technology Policy'. In Hall, B. H. & Rosemberg, N. (Eds) *Handbook of the Economics of Innovation.* Elsevier.

Stiglitz, J. (2002) *Globalization and its Discontents,* London, Penguim Books.

Storper, M. (1995) 'Regional Technology Coalitions an Essential Dimension of National Technology Policy'. *Research Policy,* 24**,** 895-911.

Storper, M. (1996) 'Innovation as Collective Action: Conventions, Products and Technologies'. *Ind Corp Change,* 5**,** 761-790.

Storper, M. & Harrison, B. (1991) 'Flexibility, hierarchy and regional development: The changing structure of industrial production systems and their forms of governance in the 1990s'. *Research Policy,* 20**,** 407-422.

Suzigan, W. (1978) 'Política Industrial no Brasil'. In Suzigan, W. (Ed.) *Indústria: política, instituições e desenvolvimento.* Rio de Janeiro, IPEA/INPES.

Suzigan, W. (2000) *Indústria Brasileira: Origem e Desenvolvimento,* São Paulo, Editora Hucitec.

Suzigan, W. & Villella, A. V. (1997) *Industrial Policy in Brazil,* Campinas, Brazil, Instituto de Economia, Unicamp.

Szapiro, M. (2003) 'Downgrading Local Capabilities in IT: the Telecom Innovation System in Campinas'. In Cassiolato, J. E., Lastres, H. M. M. & Maciel, M. L. (Eds) *Systems of Innovation and Development: Evidence from Brazil.* Cheltenham, Edward Elgar.

Szapiro, M. (2004) The Telecommunications Restructuring Process in the 90s: a Comparative Study of the Impacts on the Brazilian and Spanish Innovation System Globelics Academy - Lisbon.

Szapiro, M., Cassiolato, J. E. & Lastres, H. M. M. (2002) 'Local System of Innovation under Strain: the Impacts of Structural Change in the Telecommunications Cluster of Campinas, Brazil'. *International Journal of Technology Management,* 24

Tavares, M. D. C. (1972) *Da Substituição De Importações Ao Capitalismo Financeiro,* Rio de Janeiro, Zahar.

Teece, D., Pisano, G. & Shuen, A. A. (1997) 'Dynamic Capabilities and Strategic Management'. *Strategic Management Journal,* 18**,** 504-534.

Teixeira, F. L. (2008) 'Políticas Públicas para o Desenvolvimento Regional e Local: o que Podemos Aprender com os Arranjos Produtivos Locais (APLS)?' *Organização e Sociedade,* 15**,** 57-75.

The Economist (Various editions).

Tigre, P. B. (1993) Liberalização e Capacitação Tecnológica: O Caso da Informática Pós-Reserva de Mercado no Brasil *Ciência e Tecnologia no Brasil: Uma Nova Política para um Mundo Global.* Rio de Janeiro, Escola de Administração de Empresas da Fundação Getúlio Vargas.

Tigre, P. B., Cassiolato, J. E., Szapiro, M. & Ferraz, J. C. (2002) 'Institutional Change and Technology: the Impact of Trade Liberalisation and Deregulations on Brazil's National Innovaion System'. In Baumann, R. (Ed.) *Brazil in the 1990s - An economy in transiction.* Palgrave Macmillan.

Tigre, P. B. & Junqueira, A. J. B. (1999) 'Brazil Meets the Global Challenge: IT Policy in a Post-Liberalization Environment'. *Center for Research on Information Technology and Organizations. University of California, Irvine.*

Tigre, P. B., La Rovere, R. L., Teixeira, F. L., López, A., Ramos, D., Bercovich, N., Pinheiro, A. D. O. M., Araújo, S. & Rodrigues, R. F. (2011) 'Knowledge Cities: a Taxonomy for Analyzing Software and Information Service Clusters'. *Revista de Administração de Empresas. Fundação Getulio Vargas. Escola de Administração de Empresas de São Paulo,* v. 51**,** 15-26.

Torrisi, S. (1998) *Industrial Organisation and Innovation: an International Study of the Software Industry,* Cheltenham, Edward Elgar.

Travassos, G. H. & Kalinowski, M. (2011) iMPS 2010: Desempenho das Empresas que Adotaram o Modelo MPS de 2008 a 2010 Campinas, Softex.

Uzzi, B. (1997) 'Social Structure and Competition in Interfirm Networks: The Paradoxx of Embeddedness'. *Administrative Science Quarterly,* 41**,** 35-67.

Velho, L. & Saenz, T. W. (2002) R&D in the Public and Private Sector in Brazil: Complements or Substitutes? , INTECH Discussion Paper Series.

Veloso, F., Botelho, A. J. J., Tschang, T. & Amsden, A. (2003) Slicing the Knowledge-based Economy in Brazil, China and India: A Tale of 3 Software Industries, Softex/Massachusetts Institute of Tecnology.

Versiani, F. R. & Versiani, M. T. (1977) 'Formação Econômica do Brasil'. In Versiani, F. R. & Mendonça De Barros, J. R. (Eds) *Formação Econômica do Brasil: A Experiência da Industrialização.* São Paulo, Saraiva S.A.

Villaschi, A. (1993) The Brazilian National System of Innovation: Opportunities and Constraints for Transforming Dependency *Birkbeck College.* London, University of London.

Viotti, E. B. (2000) Passive and Active Learning Systems: A Framework to Understand Technical Change in Late Industrializing Economies and Some Evidences from a Comparative Study of Brazil and South Korea *4th International Conference on Technology Policy and Innovation - Learning and Knowledge Networks for Development.* Curitiba - Brazil.

Von Tunzelmann, N. (2003) 'Historical Coevolution of Governance and Technology in the Industrial Revolutions'. *Structural Change and Economic Dynamics,* 14**,** 365-384.

Von Tunzelmann, N. (2010) 'Alignment, Misalignment and Dynamics Network-Based Capabilities'. In Dyker, D. A. (Ed.) *Network Dynamics in Emerging Regions of Europe.* London, Imperial College Press.

Von Tunzelmann, N. & Acha, V. (2006) 'Innovation in "Low-Tech" Industries'. In Fagerberg, J., Mowery, D. & Nelson, R. (Eds) *The Oxford Handbook of Innovation.* New York, Oxford University Press.

Weber, K. C., Ramalho De Araújo, E. E., Scalet, D., De Andrade, E. L. P., Da Rocha, A. R. C. & Montoni, M. A. (2007) MPS Model-Based Software Acquisition Process Improvement in Brazil *Sixth International Conference on the Quality of Information and Communications Technology (QUATIC).*

WIT (2005) Porto Digital - Planejamento Estratégico para o Período de 2006-2008 in Costa, J. P. D. (Ed.) Recife, Porto Digital.

Yin, R. K. (2003) *Case Study Research: Design and Methods,* London, Sage Publications.

APPENDIX 1

Table A1 Main public institutions created to support the Brazilian system of innovation – from 1951 to 2004

Created in	Institution	Aim
1951	CNPq	Coordinate and foster the Brazilian scientific development.
1951	CAPES	Assure availability of skilled personnel needed for private and public entrepreneurship related to the country's development
1952	BNDES	Support entrepreneurship, mainly related to the industrial and infra-structural investments.
1960	FAPESP	Support the São Paulo state scientific development.
1967	FINEP	Manage the Financial Fund for Projects and Programmes Studies created in 1965. Later, took over from BNDES the management of the Techno-Scientific Development Fund (FUNTEC), which aimed to financially support post-graduate degrees in Brazilian universities.
1969	FNDCT	Financially support the improvement of the Brazilian scientific and technological systems.
1985	MCT	Formulate and implement the national S&T policy.
1999	Sectoral Funds for Science and Technology	Financial mechanism to support research, development and innovation projects performed in the country. There are 14 vertical sectoral funds and two horizontal ones (university industry links and the second aims to support the country's research infra-structure). Mostly funds are managed by FNDCT.
2001	CGEE	Provide studies, foresight activities and evaluation of strategies in science and technology.
2004	ABDI	Promote the Brazilian industrial and technological development through the improvement of local competitiveness and innovation.

Source: Pacheco and Corder (2009: Table 13, p.52).

Table A2 Campinas software firms: main activities

(Firm number was included for examination purposes only)

Firm	Service/ Product	Business area
Firm A	Services	Energy sector assets control; database qualification; recycle waste management
Firm B	Services	
Firm C	Services /Products	Data and communication security
Firm D	Services	Software test
Firm E	Services /Products	Digital recognition
Firm F	Services /Products	Customized Software Factory, Software Test, Industrial Maintenance Management
Firm G	Services	Console Games, Outsourcing in game development, technology for game development (middleware)
Firm H	Services /Products	Banking software, ERP for banking
Firm I	Services /Products	Outsourcing, consultancy, Supply management
Firm J	Services /Products	Customized software; embedded software for electronic turnstile
Firm K	Services	Consultancy and development of embedded software
Firm L	Services	Application Performance Management (technology that supports management of applications performance)
Firm M	Services	Genomic applications for agribusiness and human health; applications for logistic and management.
Firm N	Services /Products	Geographic Information Systems for Electric Energy Distributers
Firm O	Services	Mobility services
Firm P	Services /Products	Software reusing
Firm Q	Products	ERP
Firm R	Services	development for mobility; outsourcing for mobility, consultancy
Firm S	Services	internet social network
Firm T	Services /Products	Simulation for engineering
Firm U	Services	Agile development applications, BPM consultancy, Digital marketing, Testing factory, SAP consultancy, Business Intelligence, IT governance

Source: own elaboration, fieldwork data collection.

Table A3 Recife software firms: main activities

(Firm number was included for examination purposes only)

Firm	Service/ Product	Business area
Firm A	Services /Products	Hospital management Electronic Hospital Records WBI Business Intelligence
Firm B	Service	Business Process Management (BPM)
Firm C	Services /Products	Smart card Mobile TV Database performance consultancy
Firm D	Service	Software factory Management and organisational consultancy
Firm E	Services /Products	Outsourcing Customised systems Consultancy
Firm F	Service	Corporate integrated solutions (intranets, extranets virtual communities, websites, and communication control)
Firm G	Service	Transport management system developed in web
Firm H	Service	Software factory IT management and governance Information security Software quality and performance Web and mobile development Test processes Systems integration Performance optimizations
Firm I	Services /Products	Interactive voice response unit Computer telephony integration
Firm J	Services /Products	Information management Information recovery
Firm K	Services /Products	Operations and maintenance integrated management Customised development Equipment related middleware development
Firm L	Services /Products	Musical technology and computing Musical games (mobile and web)
Firm M	Services /Products	Educational games for schools
Firm N	Services /Products	Game development
Firm O	Services /Products	Mobile solutions Game development
Firm P	Service	Security analysis and monitoring Digital certification
Firm Q	Services /Products	Systems management for public authorities Systems management using GIS

Source: own elaboration, fieldwork data collection.

Table A4 List of interviewed organizations and their representatives

Organisation	Position
Associations	President, senior advisors
Consultancy firms	Owner/managers
Export Consortiums	Directors
Government Authorities	Coordinator, senior advisor, and directors
Higher education organisations	Superintendent
Incubators	Managers
Private non-profit research institutes	CEO, chief scientist, R&D managers and operations manager
Public research institutes	Managers and coordinators
Research Foundations	Scientific director and scientific director advisors
Social organisations	Directors, coordinators
Supporting organisations	Executive coordinator, coordinators, managers, and directors
Universities	Head of departments, professors and assistant professors
Venture Capital	Director and managers

Source: own elaboration, fieldwork data collection.

Box A1 CNAE Classification for IT software activities

62015: Customised computer programme development - Systems development to supply customised demand including activities related to module definition, internal functional specifications, tests for performance assessment; - Programming development using programme tools and languages; - Supply of documentation of customised informatics programmes; - Web design; - Development of customised projects and database.
62023: Development and licensing of customised computer - Computer systems or computer programme development (software) that allows customisation (further adaptation to customers needs) - Licensing or authorization for the use of customised informatics programme; licensing is provided by the developer.
62031: Development and licensing of non-customised computer - Computer systems or computer programme development (software) that do not allow customization, such as: operational systems, applications for companies, computer games for all platforms; licensing or authorization for the use of non-customised informatics programme; distributors of authorized non customized programmes.
62040: Consultancy in IT - Analysis to determine customers needs or potential market, and systems technical specification related to its functionalities and application areas; - Consultancy services to provide user support in the definition of systems related to the equipment types and configuration (hardware), as well as informatics programmes (software), its applications, networks and communication; - Follow-up, management and controlling of informatics projects, i.e. the coordination of activities involving the definition, implementation and operationalisation of informatics projects; - Consultancy for systems and solution integration (i.e. structuring activities and operationalisation of functional final solution, from the merging of different systems, keeping the essential characteristics); - Web sites updating; - Customising services for informatics programmes (software), i.e. activities related to the adaption of software to customer needs to screens, terminologies, tables and other systems characteristics.

Source: CNAE

APPENDIX 2 – QUESTIONNAIRES

2A Questionnaire - Firms

SECTION A - GENERAL INFORMATION - FIRM AND EMPLOYEE

FIRM

Name of firm: to be filled in by myself previous to the interview

Address of firm: to be filled in by myself previous to the interview

Year of foundation: to be filled in by myself previous to the interview

Number of employees: …………………………………...

Market: ( ) Local, ( ) Regional, ( ) National, ( ) International, ( ) All

Size of firm: Micro ( ), Small ( ), Medium ( ), Large ( )

Firm Activities: Service ( ), Product ( ), Both ( )

Was your firm awarded with the:

CMMI (Capability Maturity Model Integration)

( ) Yes, which level?..........; ( ) No

If No, is your firm considering an application? ( ) Yes, when?..........; ( ) No

MPS.br (Melhoria de Processos do Software Brasileiro)

( ) Yes, which level?..........; ( ) No

If No, is your firm considering an application? ( ) Yes, when?..........,; ( ) No

Is your firm associated to SOFTEX Recife? Yes( ) No ( )

RESPONDENT

Name of employee: …………………………………………….……………

Employee contact details:

Telephone ( ) ……………………………………...……………

Email: …………………………………………………….……………

Position held at the firm: …………………………………………………

Years of employment: ……………………………………………………

Professional background:

College/diploma: ……………………………………………………

Undergraduate degree/ year of graduation: …………………………

Postgraduate degree:

Master/ year of graduation: ……………….………………

DPhil/ year of graduation: ………………….…….…………

SECTION B - PRODUCT AND PROCESS INNOVATION

B1. Does your firm perform which software applications (e.g. banking, business)?

1.	4.
2.	5.
3.	6.

B2. Did your firm introduce a new product or a new service to the market in the past 3 years? (Please, state below whether this product/service was new to your firm or new to the market)

	No	Yes: how many	New to the Firm	New to the market	National market	International market
Product						
Service						

If the answer is **No**, please go to SECTION C.

If the answer for the question above is **Yes,** could you please describe what novelty your product/service brought to the market?

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

B3. Please, could you specify which of the following actors assisted your firm to design, develop or launch this new product or new service? (Observation: a separate sheet will be given to the respondent with the relevant list)

B4. Is there any other actor rather than the ones mentioned above that gave great assistance to your firm with regard to design, development and launching? Which ones?

B5. Considering the actor 'X', please could you tell in which stage this actor assisted your firm: design, development or launching?

B6. Could you tell if any of the following reasons were relevant for this actor assisting your firm? (obs: a separate sheet will be given to the respondent with the relevant list)
Ask about level of importance of the relevant actor:
0=not important; **1**= moderately important; **2**= very important and **3**= extremely important.

(   ) Open Information Source
(   ) Acquisition of Knowledge
(   ) Acquisition of technology
(   ) Access to new sources of financing
(   ) Access to commercial information
(   ) Innovation co-operation

B7. Is there any other reason rather than the ones mentioned above that was relevant for this actor giving assistance to your firm? Which ones?

B8. Please, could you tell if any of the listed motives were important for your firm to be linked to this actor, rating the motives as following (obs: a separate sheet will be given to the respondent with the relevant list):
0=not important; **1**= moderately important; **2**= very important and **3**= extremely important.

(   ) Trust
(   ) Opportunity
(   ) Cost
(   ) Collective identity
(   ) Knowledge: availability and accessibility
(   ) Geographical proximity

B9. Is there any other motive that was relevant for your firm interacting with this actor that was not listed? Which one?

Observation: the respondent will receive a copy of this page for answering the following questions:

B10. Is your firm at the stage of designing, developing or launching a new product or a new service?

Yes	
No	

If the answer is **No**, please go to question **B13**.

If the answer is **YES**:

B11. Please, could you list which actors are assisting your firm at this stage?
Obs.: The list with the network actors will be again provided in a separate sheet.

1 ____________________
2 ____________________
3 ____________________
4 ____________________
5 ____________________

B12. Is there any other actor rather than the ones mentioned on the list that is giving assistance to your firm? Which ones?

B13. Please, could you tick (√) what are the reasons for these actors assisting you?

( ) Open Information Source	Please name actors:___________________________
( ) Acquisition of Knowledge	Please name actors:___________________________
( ) Acquisition of technology	Please name actors:___________________________
( ) Access to new sources of financing	Please name actors:___________________________
( ) Access to commercial information	Please name actors:___________________________
( ) Innovation co-operation	Please name actors:___________________________
( ) Other, please specify	Please name actors:___________________________

B14. Is there any other reason rather than the ones mentioned above that is relevant for this actor giving assistance to your firm? Which ones?

B15. Please, could you tell if any of the listed motives are important for your firm to be linked to these actors, rating them accordingly to their importance? (List will be provided on a separate sheet)
0=not important; **1**= moderately important; **2**= very important and **3**= extremely important.

( ) Trust	Please name actors:______________________________
( ) Opportunity	Please name actors:______________________________
( ) Cost	Please name actors:______________________________
( ) Collective identity	Please name actors:______________________________
( ) Knowledge: availability and accessibility	Please name actors:______________________________
( ) Geographical proximity	Please name actors:______________________________

B16. Is there any other motive that was relevant for your firm interacting with this actor that was not listed above? Which one?

Observation: the respondent will receive a copy of this page for answering the following questions:

B17. Has your firm abandoned the design, development or launching of a new product or new service in the past 3 years?

Yes	
No	

If the answer is **No**, please go to SECTION **C**.

If the answer is **YES**:

B18. Please, could you list which actors were assisting your firm before abandonment?
Obs.: The list with the network actors will be again provided in a separate sheet.
1 ____________________
2 ____________________
3 ____________________
4 ____________________
5 ____________________

B19. Is there any other actor rather than the ones mentioned on the list that was giving assistance to your firm? Which ones?

Please, could you tick (√) what were the reasons for these actors assisting you?

( ) Open Information Source	Please name actors:__________________________
( ) Acquisition of Knowledge	Please name actors:__________________________
( ) Acquisition of technology	Please name actors:__________________________
( ) Access to new sources of financing	Please name actors:__________________________
( ) Access to commercial information	Please name actors:__________________________
( ) Innovation co-operation	Please name actors:__________________________
( ) Other, please specify	Please name actors:__________________________

B20. Is there any other reason rather than the ones mentioned above that was relevant for this actor giving assistance to your firm? Which ones?

B21. Please, could you tell if any of the listed motives were important for your firm to be linked to these actors, rating them accordingly to their importance? (List will be provided on a separate sheet)
0=not important; **1**= moderately important; **2**= very important and **3**= extremely important.

( ) Trust	Please name actors:____________________________
( ) Opportunity	Please name actors:____________________________
( ) Cost	Please name actors:____________________________
( ) Collective identity	Please name actors:____________________________
( ) Knowledge: availability and accessibility	Please name actors:____________________________
( ) Geographical proximity	Please name actors:____________________________

B22. Is there any other motive that was relevant for your firm interacting with this actor that was not listed? Which one?

Observation: the respondent will receive a copy of this page for answering the following questions:

B23. Considering that there is market demand for a new product or new service, how quick is your firm capable of responding to this new demand?
0=Very slow; **1**= Moderately Slow; **2**= Quick; **3**= Very quick

B24. How is the speed rate of responsiveness for each of the stages below?
0=Very slow; **1**= Moderately Slow; **2**= Quick; **3**= Very quick

	Design	Development	Launching
Design of a new product			
Design of a new service			
Development of a new product			
Development of a new service			
Commercialisation of a new product			
Commercialisation of a new service			

B25. Considering that there is market demand for a new product or new service, how quick does your firm interact with another network actor in order to get assistance for designing, developing, launching this new product or service?
0=Very slow; **1**= Moderately Slow; **2**= Quick; **3**= Very quick

Observation: The respondent may say that the rate of responsiveness varies accordingly to different actors. In this case the list below will then be given to the respondent, asking him/her to apply the following scale:
0=Very slow; **1**= Moderately Slow; **2**= Quick; **3**= Very quick

Actor/speed	Design	Development	Launching

Observation: the respondent will receive a copy of this page for answering the following questions:
SECTION C - MARKETING AND ORGANISATIONAL INNOVATION

C1. Did your firm implement a new marketing or new organisational method in the past 3 years? If the answer is **NO**, please go to Section **D**.
If the answer for the question above is **Yes,** could you please describe which procedures were those?
Please, for answering this section, consider the following definitions:
A **marketing innovation** is "the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing" (OECD, 2005:49).
An **organisational innovation** is "the implementation of a new organisational method in the firm's business practices, workplace organisation or external" (OECD, 2005:51).

	Novelty
Marketing innovation	
Organisational innovation	

C2. Please, could you tick (√) which actors assisted your firm to introduce a new marketing or a new organisational method? Please, state which reasons motivated your firm to be linked to each actor from the provided list rating as follows).
0=not important; **1**= moderately important; **2**= very important and **3**= extremely important.

Actors	Marketing	Organisational

C3. Is there any other motive that was relevant for your firm interacting with this actor that was not listed? Which one?

Observation: the respondent will receive a copy of this page for answering the following questions (template for Recife):

SECTION D - CONSTRAINTS ON INNOVATION

D1. Considering the following factors as constraints on innovation to your firm, please could you tick (√) which of the actors below you looked for assistance in order to alleviate this/these constraint(s)? Please, relate each actor to the motive as following:
0=not important; **1**= moderately important; **2**= very important and **3**= extremely important.

Actors /Constraints	Cost of finance	Availability of finance	Uncertain demand for innovative goods	Need to meet government regulations	Lack of qualified personnel	Lack of information on technology	Lack of information on markets	Need to meet international regulations
Porto Digital Management Unit								
C.A.I.S. do Porto								
SoftexRecife								
C.E.S.A.R								
Cin – UFPE								
UNICAP								
CEFET-PE								
ITEP								
SECTMA								
FACEPE								
AD-Diper								
SEBRAE Pernambuco								
ASSESPRO Pernambuco								
FINEP								
BNDES								
Customers								
Supplier								
Other, please specify:								
None of the above								

SECTION E – GOVERNMENT POLICY ASPECTS

E1. Was your firm engaged in any process of government programme/policy formulation directed to the software industry in the past 5 years?
Yes, which programme was this? Why?
No, why?

E2. Did you get in contact with the government body for engaging in this process or were contacted by them?

E3. Why did you contact them? **OR** Why do you think that your firm was contacted?

E4. In your opinion, do you think this programme formulation considered your demands and comments?
Yes, how?
No, why?

E5. In your opinion, did the programme results meet your demands?

E6. In your opinion, how do think that the programme affected the network as a whole?

E7. In your opinion, how do you think that the programme is going to interfere in your relation with other actors of the network?

E8. In your opinion, what do you think that are the strengths of the network?

E9. In your opinion, what do you think that are the weaknesses of the network?

E10. In your opinion, how do you think that a new government programme could improve the network as a whole?

E11. In your opinion, how do you think that the programme could be improved?

2B Questionnaire – Supporting organisations

SECTION A
GENERAL INFORMATION –ORGANISATION AND EMPLOYEE

INDUSTRIAL ASSOCIATION (to be filled previous to interview)

Name of organisation: ………………………………………….

Address of organisation: ………………………………………….

Number of firms associated: ……….

Number of employees: ……….

RESPONDENT

Name of employee: ……………………………………….……………

Employee contact details:

Telephone (   ) ……………………………………..……………

Mobile phone:……………………………………….……………

Email: ……………………………………………….……………

Position held at the organisation: ……………………………………………

Years of employment: ……………………………………………………

Professional background:

College/diploma: ……………………………………………………

Undergraduate degree/ year of graduation:……………………………

Postgraduate degree/ year of graduation:

Master/ year: ……………….……………

DPhil/ year: ……………….…………….

SECTION B

B1. How did you get involved with the software industry? (Background information about the interviewee)

B2. Did your organisation participate in the formulation/implementation of any programme/policy directed to the software industry?

B3. If yes, was your organisation contacted by any government body to engage in the formulation/implementation process? (if no, go to B6)

B4. If yes: in your opinion, which reasons made the government seek for an interaction with your organisation for the formulation/implementation of this programme?

B5. How did your involvement happen? (Formal basis or informal basis?)

B6. **OR** Did your organisation contact the government body so that you could get involved in the formulation/implementation process? If yes, why did you want to get involved in the formulation/implementation process?

B7. In your opinion, were your comments and demands incorporated by the programme? Why?

B8. In your opinion, which reasons make software firms interact with your organisation?

B9. How does this interaction happen? Is it on a formal basis, or on an informal basis?

B10. Is your organisation contacted by other actors of the network? (e.g.: universities, SOFTEX, research centres?)

B11. In your opinion, which reasons drive this interaction?

B12. How does this interaction happen? (Formal basis or informal basis)

B13. Does your organisation conduct activities to promote innovation in the software industry? If no, why does not it?

B14. If yes, which ones? (e.g.: training, technology dissemination, technological upgrading, normalisation and standardisation?)

B15. In your opinion, what are the strengths of the network?

B16. In your opinion, what are the weaknesses of the network?

B17. In your opinion, which and how the strengths/weaknesses mentioned above could be improved?

B18. In your opinion, who are the key actors of the network? Why?

2C Questionnaire – policy makers

SECTION A
GENERAL INFORMATION – GOVERNMENT BODY AND EMPLOYEE

<u>GOVERNMENT BODY</u>

Name of government body: …………………………………………….

Address of government body: ………………………………………….

Number of employees: …………………………………...

<u>RESPONDENT</u>

Name of employee: ……………………………………….……………

Employee contact details:

Telephone (   ) …………………………………...……………

Mobile phone:…………………………………….……………

Email: ……………………………………………….……………

Position held at the government: ……………………………………………

Years of employment: ……………………………………………………

Professional background:

College/diploma: …………………………………………………

Undergraduate degree/ year of graduation:……………………………

Postgraduate degree/ year of graduation:

Master/ year: ……………….……………

DPhil/ year: ……………….…………….

SECTION B

B1. How did you get involved with the ICT industry? (Background information about the interviewee)

B2. Did you participate in the formulation of any programme/policy directed to the software industry?

B3. Did **firms** participate in the formulation process of this programme? If yes, which ones (local, multinational, which size)?

B4. Did **firms** contact your government body to engage in the formulation process? If yes: which ones (local, multinational, which size)?

B5. In your opinion why did these **firms** want to be involved in the formulation process?

B6. Were **firms** contacted by your government body to be engaged in the formulation process? If yes, which ones and why were they?

B7. Did **other actors** (e.g. Universities, Industrial Associations, SEBRAE) of the network participate in the formulation process of this programme? If yes, which ones?

B8: Were they contacted by your government body to be engaged in the formulation process or they contacted the government? Why were they contacted? **OR** why they contacted you?

B9. How do firms and other actors' involvement happen? Is it on a formal basis, or on an informal basis?

B10. In your opinion, which reasons made the government seek for an interaction with firms and other actors? (get a separate reason for each of the mentioned actors by the interviewee).

B11. In your opinion, what motivates the interaction with each actor? (come with elements about trust, opportunity, etc.)

B12. Were firms and other actors comments incorporated in the programme/policy? Why?

B13. How does the implementation stage happen, do network actors engage in the implementation of the programme/policy? (If yes: how do they engage in?; If no: why do not they?

B14. In your opinion, in general terms why firms contact your government body and how do they do so? (e.g. use the Industrial Federation, Industrial Association, etc).

B15. In your opinion, what are the strengths of the network?

B16. In your opinion, what are the weaknesses of the network?

B17. In your opinion, which and how the strengths/weaknesses mentioned above could be improved?

B18. In your opinion, who are the key actors of the network? Why?

2D Questionnaire – University, technical education school, research centre

SECTION A
GENERAL INFORMATION – ORGANISATION AND EMPLOYEE

<u>Organisation</u> (to be filled previous to interview)

Name of organisation: …………………………………………….

Address of organisation: ………………………………………….

Year of foundation: ………………………………………

Number of employees: …………………………………...

Activity: (   ) Undergraduate   (   ) Postgraduate

(   ) Technical School   (   ) Research Centre

<u>RESPONDENT</u>

Name of employee: ……………………………………………..……………

Employee contact details:

Telephone (   ) ……………………………………..……………

Mobile phone:……………………………………….……………

Email: ………………………………………………..……………

Position held at the organisation: ……………………………………………

Years of employment: ……………………………………………………

Professional background:

College/diploma: ……………………………………………………

Undergraduate degree/ year of graduation:……………………………

Postgraduate degree/ year of graduation:

Master/ year: ………………..……………

DPhil/ year: ………………..…………….

SECTION B - RESEARCH RELATED QUESTIONS

B1. Which are your research topics in software and how are they related to the software industry?

B2. Do firms collaborate in any of these research areas?

If yes, which firms are those? (local, multinational, micro, small, medium, large)

B3. In your opinion, what are the reasons for those collaborations? (what do each of you seek in the partnership?)

B4. How do these collaborations normally happen? Do you approach firms? **OR** Do firms approach you?

B5. Which kind of collaborations are they?

(   ) Formal   (   ) Informal

B6. In your opinion, what are the motives for those interactions? (check from list of motives below)

B7. Is there a broker to mediate the collaboration?

If yes: which one is it? In your opinion, why do think that a broker is needed?

B8. Do other organisations collaborate in these research areas?

B9. In your opinion, what are the reasons for those collaborations? (what do each of you seek in the partnership?)

B10. How do these collaborations normally happen? Do you approach them? **OR** Do they approach you?

B11. Which kind of collaborations are they?

(   ) Formal

(   ) Informal

B12. In your opinion, what are the motives for those interactions? (check from list of motives below)

B13. Is there a broker to mediate the collaboration?

If yes: which one is it? In your opinion, why do think that a broker is needed?

B14. In your opinion, what are the motives for those interactions, with the broker presence? (check from list of motives below)

List of motives:
A. Trust
B. Opportunity
C. Cost
D. Collective identity
E. Knowledge: availability and accessibility
F. Geographical proximity

SECTION C – EDUCATION RELATED QUESTIONS

C1. Which are the taught programmes that are related to the software industry?

C2. How are the syllabuses of these programmes created? Are they discussed only internally? Do other actors participate in their formulation process? Or in any changing process?)

C3. What are the aims of these programmes (e.g., strength academia in this area, provide human resources for the private sector?)

C4. Is there any taught programme related to the software industry that you offer to the private sector?

C5. How are the syllabuses of these programmes created? Are they discussed only internally? Do other actors participate in their formulation process? Or in any changing process?)

C6. Why was this programme created? (e.g., to meet a demand from the private sector?)

C7. Which audience is this programmes targeting? (firms, which firms?; technological institutes, previous graduates?)

C8. How many students do you have enrolled per year in each programme?

C9. What is the profile of your students?

C10. How do you advertise this programme? (e.g., SOFTEX, industrial associations?)

SECTION D – POLICY AND NETWORK RELATED QUESTIONS

D1. Did the government seek for your expertise when formulating any programme for the software industry in the past 10 years?

D2. If yes, how did that happen? (formal or informal basis)

D3. In case of informal basis: is the government representative a graduate/ex-employee/ faculty who is on temporary leave to work for the government?

D4. In your opinion, what were the reasons that made your organisation consulted **OR** not consulted? (e.g., scientific reasons, provision of human resources?)

D5. In your opinion, were your comments incorporated in the programme? Why?

D6. In your opinion, were your demands incorporated in the programme? Why?

D7. In your opinion, what are the strengths of the government policy?

D8. In your opinion, what are the weaknesses of the government policy?

D9. In your opinion, what are the strengths of the network?

D10. In your opinion, what are the weaknesses of the network?

D11. In your opinion, which and how the strengths/weaknesses mentioned above could be improved?

D12. In your opinion, who are the key actors of the network? Why?